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A Falling Meteorite. From a painting made for this work by Benson B. Moore, under the supervision of the author

MINERALS FROM EARTH AND SKY

PART I

THE STORY OF METEORITES

By

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Head Curator, Department of Geology,
U. S. National Museum

PART II

GEMS AND GEM MINERALS

By

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Department of Geology, U. S. National Museum

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PREFACE

THIS book is not intended for the specialist; rather for those who—whether or not engaged in other lines of work—are interested in the progress of science and in the method of its progression. It was with the latter particularly in mind that the narrative form was adopted for certain chapters. How a conclusion has been arrived at is, to the public mind, believed to be of as great interest as the conclusion itself.

GEORGE P. MERRILL.

PART I

THE STORY OF METEORITES

By

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Head Curator, Department of Geology,
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CHAPTER I

INTRODUCTORY AND HISTORICAL

FAR up in the remote and silent reaches of the sky there may be seen occasionally on almost any cloudless night a faint moving spark of light. Appearing suddenly and apparently from nowhere, it travels rapidly through a section of the sky, for a moment increasing in brightness, and then as quickly and silently disappearing. It is as though some unseen, gigantic, and sacrilegious hand had scratched a match upon the portals of the heavens. We *call* it a meteor, but what is it? It is possible that, as though in answer to the question, one of these mysterious objects may assume a more tangible form and come to earth, no longer noiselessly, however, but with a hiss, roar, and crash of thunder, brightening the heavens as a flash of lightning, and then as suddenly subsiding. Yet again we ask, what is it?

In considering this matter, let us first indulge in a few commonplaces concerning our planet and its surroundings. A background is needed for the story we shall attempt to tell.

Space, as we look out upon it during the day, imparts a sense of emptiness, of vacancy. It is only after sundown, and particularly when we look toward the Milky Way, that we begin to appreciate the vast number of bodies like our sun, which we call stars and with which we are associated. Photographs through telescopic lenses (Plate 1) vastly increase the impressiveness of the view, but even these fail to convey a complete idea of actual conditions. The stars, as stated, are suns; and some of them, no doubt, like our own, have planets, nonluminous in themselves, wholly invisible to the naked eye, and made visible with the telescope only by a slight and temporary dimming of the light when one happens to cross the face of a star under observation. These planets again may have still smaller bodies revolving in known and regular orbits about them, as our Jupiter has its moons. None of these is stationary, but all are progressing through space in a regular, orderly manner. The astronomer can tell with a fair degree of exactness their relative position a thousand years ago and what it will yet be a thousand years hence.

In addition there are untold millions of smaller bodies, the presence of which is wholly unsuspected by the casual observer. These, in seemingly erratic courses, are flying through space in every conceivable direction and at almost incredible speed. Giving no light by themselves, of a size too small to yield an appreciable amount of reflected light, it is only when in their wanderings they become momentarily luminous through contact with the earth and its atmosphere that they make their presence known.

Now every schoolboy knows that when he throws his ball it remains in the air only so long as the speed imparted to it is sufficient to overcome the attractive power of gravity. When this slackens, it falls to the ground. So with these various bodies which we have just considered. All are traveling through space at varying speeds and at rates well-nigh incredible, unthinkable to us even with our recently acquired knowledge of speeding airplanes and high-power guns. The writer once stood on the deck of a steamer opposite Indian Head, on the Potomac, and watched one of the enormous engines of warfare in actual practice. There came a flash, then a cloud of smoke, and later the roar of the report. Turning leisurely and looking down the river, there was seen in a few moments the splash of the projectile as, with propelling force spent, it yielded to the attraction of gravity and came to rest. Now the shell from this piece of ordnance had a muzzle velocity of some 2,700 feet per second; or, in round numbers, would travel a mile in two seconds. Startling as such speed may seem, it is slow compared with that of the so-called heavenly bodies by which we are surrounded and upon which, from our earthly viewpoint, we have been gazing. Our rotund earth itself is traversing its seemingly barren void at a differential speed of 19.8 miles per second. Our moon is traveling about our earth, the earth about the sun, and the sun in its turn about a greater sun, and it is through the fine adjustment of speed and gravitational attraction alone that they are enabled to hold their relative distances. It is speed, speed and mass, which holds the entire visible universe in its present seemingly stable form. But, one may ask, whence the speed?

> With what an awful world-revolving power
> Were first the unwieldy planets launch'd along
> The illimitable void!

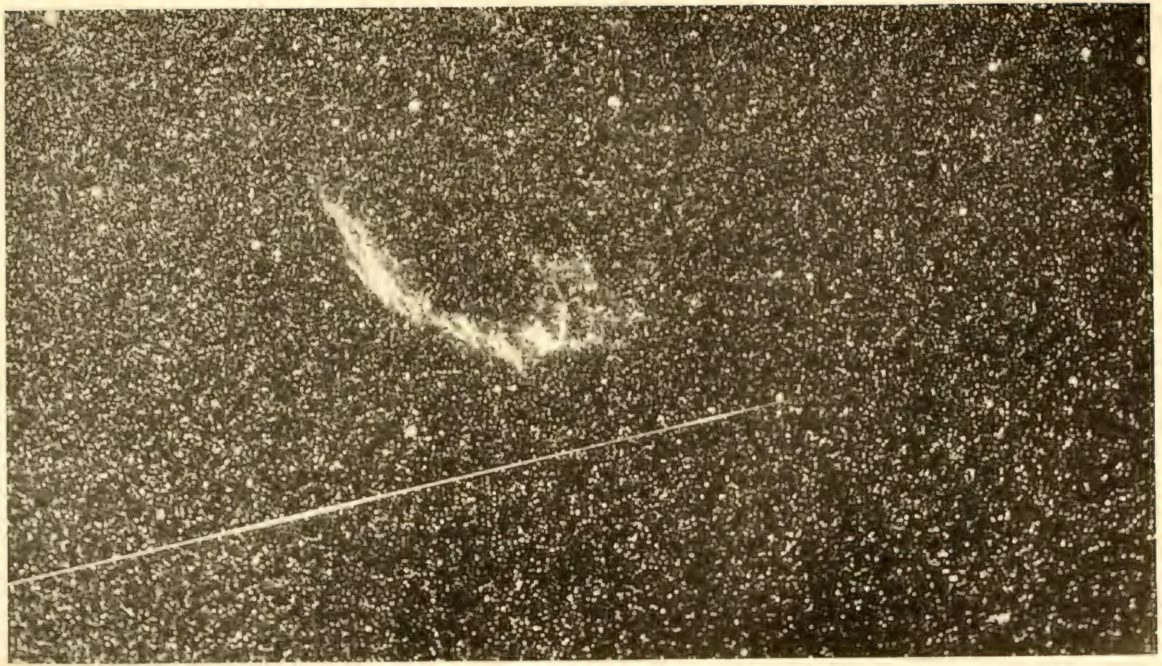
writes Thomson in his *Seasons*. What, indeed, gave them this "awful world-revolving power?" This is a question we shall not attempt to answer. We are already beyond our depth in space—let us hasten back to earth and continue our story of the smallest and most insignificant of these celestial bodies, which are to be the subject of our studies. Whence their origin and the source of that awful power that launched them on their way is as yet known only in theory. Their destiny can, however, be foretold. Such are the laws of gravity that, whenever one of them comes in its wanderings sufficiently within the attractive power of a larger wanderer, it is drawn toward it and perhaps, like the moth in the flame, completely consumed. Astronomers tell us that each day 400,000,000 of them enter the earth's atmosphere, and that of these 20,000,000 are of sufficient size to form a shooting star, or *meteor*—a streak in the sky such as that to which attention was first called; but so great is their speed and such the resistance of the earth's atmosphere that even in the few seconds of their flight they become heated to the point of incandescence and even consumed. Occasionally —rarely—one is of sufficient size to survive in part and comes to earth, a scorched residual of stone or metal to which is given the name *meteorite*.

There are those who argue that our entire earth was built up by a process of accretion—an ingathering of these flying bodies. If so, time indeed must have been illimitable. "In the beginning" is pushed back beyond the possible reaches of human imagination; for it has been estimated from such scanty data as are available that the earth's mass is, at the present rate of incoming matter, increased by only some 93,000 tons annually, an amount which, if continued for 350,000,000 years and evenly distributed, would form a film of but one inch in thickness over the entire surface.

But enough of this. Let us consider an actual occurrence of one of these incoming bodies as given in the publications of the time.

On the evening of February 12, 1875, at half past ten o'clock, there suddenly appeared over northern Missouri, at a height estimated as fifteen miles, a bright light, seemingly emanating from a solid body which passed rapidly from the southwest to the northeast into southern Iowa, where, at an altitude of about two miles, an explosion took place, sending to the earth a shower of irregularly shaped stones varying in weight from a few ounces to many pounds and aggregating not less than 700 pounds. Accounts of the phenomenon as given by eyewitnesses are somewhat variable, though rarely contradictory. By one observer, the object was described as oblong in shape, with a train ten or twelve times the length of the body, giving an intensely brilliant light of crystalline whiteness at the center, fiery red on the bottom, and throwing out

PLATE 1



Looking into "empty space." The white spots are stars; the straight line a meteor trail. From a photograph. (Courtesy of Yerkes Observatory)

PLATE 2

Fall of a meteorite in the midst of a field. (From *L'Astronomie*) red sparks and purplish jets of flame. To another, it was of horseshoe shape greatly elongated, the outer edge very brilliant, then a narrow dark space with a core of intense brilliancy, so vivid as to blind the eyes for a moment. Again, to an observer at the Iowa Agricultural College, it appeared in the form of an immense rocket with streamers flowing from the hinder part, the front being smooth and curved like a saber. Its color was at first brilliantly white, illuminating the sky like a flash of lightning, fading gradually into yellow, then to deep orange, almost scarlet, when it burst. The phenomenon was observed throughout a region at least 400 miles in length, from southwest to northeast, and 250 miles in breadth. The "explosion" mentioned gave rise to detonations so violent as to shake the earth and to jar the windows like the shock of an earthquake, and was compared by some to the discharge of a forty-gun battery. This was followed by a rushing, rumbling, and crashing sound that seemed to follow the meteor's path. The product of the fall, as already noted, was a large number of irregular fragments of stone, the largest of which weighed perhaps 120 pounds. They were mostly entirely covered with a black coating beyond question due to the fusion and sudden cooling of the outer portions of the fragments in their passage through the atmosphere. (Plates 3 and 5.) A feature of additional interest lies in the fact that but a portion of the meteor fell at this point. What seemed the larger portion continued on its way and, if it fell to earth, was never heard from.

This description, typical of many, will serve to illustrate the ordinary phenomenon of a shooting star and meteoric fall. It is not strange that such phenomena should early have attracted widespread attention. Neither is it strange that there should have been among those not actual witnesses of the event a considerable amount of skepticism regarding the fall of stones from the heavens. Like instances have, however, been recorded from very early times, and it is altogether probable that such Scriptural references as the following refer to similar phenomena:

> And the stars of heaven fell unto the earth, even as a fig tree casteth her untimely figs, when she is shaken of a mighty wind. (Rev. vi, 13.)
>
> And there fell a great star from heaven, burning as it were a lamp. (Rev. viii, 10.)
>
> And there appeared another great wonder in heaven; and behold a great red dragon, having seven heads and ten horns, and seven crowns upon his heads.
>
> And his tail drew the third part of the stars of heaven, and did cast them to earth. (Rev. xii, 3, 4.)

Satisfactory pictorial illustrations of such events are not abundant, for the simple reason that the period of flight is too brief for even the most experienced of snapshot photographers or rapid delineators and that the phenomena are comparatively rare. The fall invariably occurs at unexpected moments and in unexpected places and few are prepared to view it with the calm and discriminating eye which scientific accuracy demands. Those illustrations which have thus far been published were unquestionably drawn from memory, aided in some cases by a facile imagination. There is about them, however, nothing incredible, and it is felt that the composite view given in our frontispiece may be accepted as conveying an approximately correct idea.

The description of the Homestead, Iowa, fall, from which we have so fully quoted, is a modern one. It is that of a fall which took place many years after the possible fall of "stones from the sky" had become an established fact. Let us go back and cite an earlier occurrence and note the effect upon the general public as well as upon the scientific mind, and also the gradually expanding views held as evidence was presented by succeeding falls. Naturally but few of the many can be considered, and the reader is referred to the classic works of Chladni, Izarn, and the *Catalogue* of Biot for further details. Chladni believed that the oldest undoubted meteoric fall of which there was authentic record was that of Crete, which dates back somewhat doubtfully to the year 1478 B.C. Greater interest and certainty are attached to an account given by Pliny in the second book of his *Naturall Historie* (Holland's translation), the Olympian year 78 corresponding to that of 468 B.C. Writing of "stones falling downe from the skie" he says:

Among the Greekes there is much talke of *Anaxagoras Clazomenius*, who by his learning and skill that he had in Astronomie, foretold in the second year of the 78 Olympiad, what time a stone should fall from out of the Sunne: and the same happened accordingly in the day-time, . . . which stone is shewed at this day as bigge as a waine load, carrying a burnt and a dust color: at what time as a comet or blazing starre also burned in those nights. Which if any man beleeve that it was fore-signified, must needs also confesse, that this divinitie or fore-telling of *Anaxagoras* was more miraculous and wonderfull than the thing itselfe: and then farewell the knowledge of Natures workes, and welcome confusion of all, in case we should beleeve that either the Sunne were a stone, or that ever any stone were in it. But, that stones fall oftentimes downe, no man will make any doubt. In the publicke place of Exercise in Abydos, there is one at this day upon the same cause preserved and kept for to be seene, and held in great reverence. It is of but a meane and small quantitie, yet it is that which the self-same *Anaxagoras* (by report) fore-signified that it should fall in the midst of the earth. There is one also at Cassandria. . . . I myselfe have seene another in the territorie of the Vocantians, which was brought thither but a little before.

The earliest authentic meteorite seen to fall and of which portions are still preserved is that of Ensisheim, in Ober-Elsass, Germany. A literal translation of an account of this incident is given below:

On Wednesday, Nov. 7, the night before St. Martins day, in the year of our Lord 1492, a singular miracle happened: for between the hours of eleven and twelve a loud clap of thunder took place, with a long-continued noise, which was heard at a great distance: and a stone fell from the heavens in the Ban of Ensisheim which weighed 260 pounds: and the noise was much louder in other places than here. . . . It did no hurt, except that it made a hole there. It was afterwards transported thence: and a great many fragments were detached from it . . . It was then deposited in the church, with intention of sus-

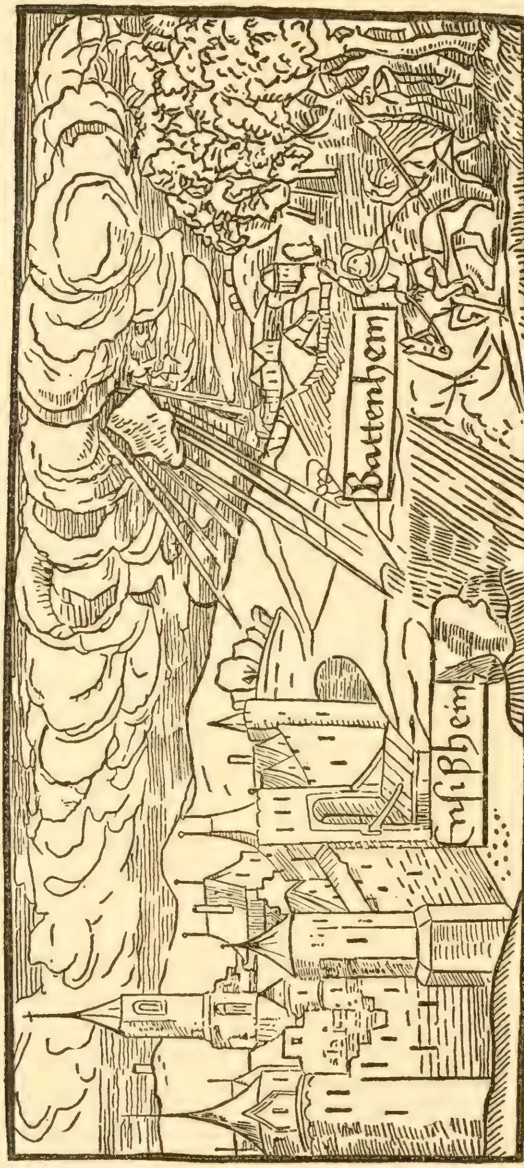


FIG. 1. Fall of meteorite at Ensisheim, Germany, in 1492 (From an old woodcut, originally colored)

pending it as a miracle: and a great many people came hither to see this stone, respecting which there were singular discourses. But the learned said they did not know what it was, for it was something supernatural that so large a stone should fall from the atmosphere: but that it was a miracle of God: because, before that time, nothing of the kind has ever been heard of, seen, or described. When this stone was found, it had entered the earth to a depth equal to the height of a man. What everybody asserted was, that it had been the will of God that it should be found. And the noise of it was heard at Lucerne, at Villing, and many other places, so loud that it was thought the houses were all overturned. . . . The people talked a great deal of this stone which was suspended in the choir, where it still is, and many come to see it. And when King Maximilian was here, the Monday after Saint Catherines day of the same year, his Excellency caused the stone which had fallen to be carried to the castle; and after conversing a long time with his Lords, he said: The people of Ensisheim should take it; and he gave orders that it should be suspended in the church and that no person should be permitted to take any part of it.[1] His Excellency however took two fragments: one of which he kept and the other he gave to Duke Sigismund of Austria.[2]

Equally worthy of reproduction in its entirety is an account of a fall said to have taken place in Berkshire, England, in 1628. Unfortunately none of the material of this fall is known to have been preserved. The account, as given by Lockyer in his *Meteoritic Hypothesis*, is stated to be from "a very rare tract, a copy of which is in the British Museum" and which bears the following title:

Looke Vp and See Wonders: a miraculous Apparition in the Ayre, lately seen in Barke-shire at Bawlkin Greene, neere Hatford, 9th April, 1620. (Imprinted at London for Roger Mitchell.)

[1] Nevertheless eager collectors have been successful in scattering fragments of the stone widely. Wülfing lists sixty collections in various parts of the world containing each from one to 400 grams of it, 54,800 grams still remaining at Ensisheim; in the National collections at Washington the fall is represented by two pieces weighing respectively 200 and 250 grams. The original weight of the entire mass is given as 127,000 grams.

[2] The condition of the popular mind regarding such evidence is shown by a letter written by an eyewitness of the fall. This opens as follows: "The cause of my writing to you at this time is by reason of the accident that the Lord sent among us. I have heard of the Lord by the hearing of the ear as the prophet speaketh, but now mine eyes hath seen him. You will marvel that I write thus, for no man hath seen God at any time yet in his works we see him daily, *but now after a more special manner.*" Then after giving a clear account of the whole occurrence, the writer concludes with an exhortation to unbelievers: "Now let the atheist stand amazed at this work of the Lord."

It begins as follows:

So Benummed wee are in our Sences, that albeit God himselfe Holla in our Eares, wee by our Wills are loath to heare him. His dreadfull Pursiuants of *Thunder* and *Lightning* terrifie vs so long as they have vs in their fingers, but beeing off, wee dance and sing in the midst of our Follies.

Then, continuing, the author tells how

the foure great quarter-masters of the World (*the foure Elements*) . . . have bin in ciuill warres one against another . . . As for Fire, it hath denied of late to warme vs, but at vnreasonable rates and extreame hard conditions. But what talke I of this earthy nourishment of *fire*? How have the *Fires* of Heaven (some few years past) gone beyond their bounds, and appeared in the shapes of Comets and Blazing Starres? . . . The *Aire* is the shop of Thunder and Lightning. In that, hath the late bin held a Muster of terrible enemies and threatners of Vengeance, which the great Generall of the Field, who Conducts and Commands all such Armies (*God Almighty*, *I meane*) auert from our Kingdome, and shoote the arrowes of his indignation some other way, upon the bosomes of those that would confound his Gospell . . . Many windowes hath he set open in Heaven, to shewe what Artillery hee has lying there, and many of our Kings have trembled, when they were shewne vnto them. What blazing Starres (euen at Noone-dayes) in those times hung houering in the Aire? How many frightfull Ecclipses both of Sun and Moone? . . . It is not for man to dispute with God, why he has done this so often . . . but, with feare and trembling casting our eyes vp to Heauen, let us now behold him, bending his Fist onely, as lately he did to the terrour and affrightment of all the Inhabitants dwelling within a Towne in the County of Barkshire . . . The name of the Towne is *Hatford*, some eight miles from *Oxford*. Ouer this Towne, vpon Wensday being the ninth of this instant Moneth of *April* 1628, about five of the clocke in the afternoone this miraculous prodigious, and fearefull handyworke of God was presented . . . The weather was warme, and without any great shewe of distemperature, only the skye waxed by degrees a little gloomy, yet not so darkened but that the Sunne still and anon, by the power of the brightnesse, brake through the thicke clouds. . . .

A gentle gale of wind then blowing from betweene the West and Northwest, in an instant was heard, first a hideous rumbling in the *Ayre*, and presently after followed a strange and fearefull peal of Thunder running up and downe these parts of the Countrey, but it strake with the loudest violence, and more furious tearing of the *Ayre*, about a place called *The White Horse Hill*, than in any other.

The whole order of this *thunder* carried a kind of Maiesticall state with it, for it maintayned (to the offrighted Beholders' seeming) the fashion of a fought Battaile.

It beganne thus: First, for an onset, went off one great *Cannon* as it were of *thunder* alone, like a warning peece to the rest that were to follow. Then a little while after was heard a second; and so by degrees a third, vntill the number of 20 were discharged (or there-abouts) in very good order, though in very great terror.

In some little distance of time after this was audibly heard the sound of a Drum beating a Retreate. Amongst all these angry peales shot off from Heauen, this begat a wonderful admiration, that at the end of the report of euery cracke, or *Cannon-thundering*, a hizzing Noyse made way through the *Ayre*, not unlike the flying of *Bullets* from the mouthes of great Ordnance; and by the judgment of all the terror-stricken witnesses they were *Thunder-bolts*. For one of them was seene by many people to fall at a place called Bawlkin Greene, being a mile and a half from Hatford: Which *Thunder-bolt* was by one Mistris *Greene* caused to be digged out of the ground, she being an eye-witnesse, amongst many other, of the manner of the falling.

The form of the *Stone* is three-square, and picked in the end; in colour outwardly blackish, somewhat like Iron: crusted over with that blackness about the thickness of a shilling. Within it is a soft, of a gray colour, mixed with some kind of minerall, shining like small peeces of glasse.

This *Stone* brake in the fal: The whole peece is in weight nineteene pound and a halfe: The greater peece that fell off weigheth five pound, which with other small peeces being put together, make foure and twenty pound and better. . . .

The following condensed account of a fall near Laigle, France, as given by Biot in *Tilloch's Philosophical Magazine*, is also worthy of reprinting in its entirety on account of its importance in settling in the minds of scientific men the question of the ultraterrestrial origin of meteorites.

On Tuesday, April 26, 1802, about one in the afternoon, the weather being serene, there was observed from Caen, Pont-Audemer, and the environs of Alençon, Falaise, and Verneuil, a fiery globe of a very brilliant splendour, which moved in the atmosphere with great rapidity.

Some moments there was heard at Laigle, and in the environs of that city to the extent of more than thirty leagues in every direction, a violent explosion which lasted five or six minutes.

At first there were three or four reports like those of a cannon, followed by a kind of discharge which resembled a firing of musketry; after which there was heard a dreadful rumbling like the beating of a drum. The air was calm and the sky serene, except a few clouds, such as are frequently observed.

The noise proceeded from a small cloud which had a rectangular form, the largest side being in a direction from east to west. It appeared motionless all the time that the phenomenon lasted. But the vapour of which it was composed was projected momentarily from the different sides by the effect of the successive explosions. This cloud was about half a league to the north-north-east of the town of Laigle; it was at a great elevation in the atmosphere, for the inhabitants of two hamlets a league distant from each other saw it at the same time above their heads. In the whole canton over which this cloud hovered, a hissing noise like that of a stone discharged from a sling was heard, and a multitude of mineral masses exactly similar to those distinguished by the name of *meteoric stones* were seen to fall at the same time.

The district in which the stones fell forms an elliptical extent of about two leagues and a half in length and nearly one in breadth, the greatest dimension being in a direction from south-east to north-west, forming a declination of about 22°. This direction which the meteor must have followed is exactly that of the magnetic meridian; which is a remarkable result.

The largest of these stones fell at the south-east extremity of the large axis of the ellipse; the middle-sized ones fell in the centre, and the smallest at the other extremity. It thereby appears that the largest fell first, as might naturally be supposed.

The largest of all those which fell weigh 17½ pounds. The smallest I saw weigh about two gros, which is the thousandth part of the former. The number that fell is certainly *above* two or three thousand.

In this account I have confined myself to a simple relation of facts; I have endeavored to view them as any other person would have done, and I have employed every care to present them with exactness. I leave to the sagacity of philosophers the numerous consequences that may be deduced from them; and I shall consider myself happy if they find that I have succeeded in placing beyond a doubt the most astonishing phenomenon ever observed by man. (See also page 26.)

In Gilbert's *Annalen* for 1806 is an account of a stone shower which gives interesting evidence of an ability to *see things*. Reference is made to a folio volume of woodcuts in the ducal library of Gotha where is recorded a fearful phenomenon and miracle which was seen on March 1, 1564, between Mechel and Brussels. The sky on the occasion was clear at first, but about nine o'clock became fiery, throwing down a reflection upon the earth so that everything became yellowish. In the meantime there appeared in the sky figures of three men in royal robes and with crowns upon their heads, remaining visible for nearly three-fourths of an hour, when they gradually drew near together and in the course of another fifteen minutes disappeared. Then frightful stones fell, large and small, some of which were five or six pounds in weight. So far as known none of this material has found its way into collections.[3]

The first fall of a meteoric stone in America of which there is a satisfactory record was that of Weston in southern Connecticut. This took place on the morning of December 14, 1807, at about half past six. It was observed by a large number of persons and offers a good illustration of the fate that has befallen many a meteoric stone on similar occasions. The account here given is mainly an abstract from the report of Professors Silliman and Kingsley in the *American Journal of Science*.

The meteor was first seen as a globe of fire just passing behind a dark cloud which did not, however, wholly obscure it, the appearance being compared to that of the sun seen through a mist. It came from the north, in a direction nearly perpendicular to the horizon, never making angles with it of more than four or five degrees, and appeared about two-thirds as large as the full moon. When not obscured by clouds it flashed with a vivid light, compared to that of the so-called heat lightning. A conical train of waving paler light, in length some ten or twelve diameters of the body, followed it. The interval of appearance and disappearance was estimated at about

[3] A good historical account of the falls known at the time and the attendant phenomena, together with the gradually developing views on the subject, is given in J. Izarn's *Des pierres tombées du ciel, ou Lithologie atmosphérique*, Paris, 1803. This account, which cannot be reproduced here, closes with the remark: "Finally it is henceforth useless to attempt to either question or verify the fact [of their fall] and it only remains for us to become better acquainted with it in order to find an explanation."

thirty seconds, and it did not vanish instantly but grew fainter and fainter until it finally disappeared about fifteen degrees short of the zenith.

Some thirty or forty seconds after its disappearance there occurred three loud and distinct reports like those of a four-pound cannon close at hand. These were followed by a rapid succession of lesser reports so close together as to produce a continuous rumbling like that of a cannon ball rolling over a floor, or a wagon running rapidly down a long and stony hill. The noise continued about as long as the meteor was rising, and died away apparently in the direction from which it came. The explosions were in all cases followed by a loud whizzing or roaring sound which "excited in some the idea of a tornado; in others of a large cannon shot in rapid motion; and it filled all with astonishment and apprehension of some impending catastrophe." In every instance, immediately after this was heard a sudden and abrupt noise, like that of a ponderous body striking the ground in its fall. After the explosions there fell a number of pieces of stone scattered over a considerable area, the most remote being nine or ten miles from each other in a line closely following the direction of flight. With but one exception the stones were more or less broken. Over 15,000 grams from this fall are preserved in the Mineralogical Museum of Yale University.

The most northerly fall was within the limits of Huntington, where the meteorite struck a granite bowlder with a loud noise and was broken into fragments, the largest of which was not larger than a goose egg. This is stated to have been still warm when picked up half an hour later. A piece weighing some thirty-five pounds, which seemed to result from the second explosion, fell about five miles distant from the first, burying itself to a depth of two feet in the ground. This was unfortunately broken up and scattered. Later a piece stated to weigh seven to ten pounds was found half a mile northwest of this, and one weighing thirteen pounds about the same distance northeast. Two miles southeast of the place where the 35-pound mass fell, a piece thought to have weighed twenty to twenty-five pounds was found but this also was broken up. The largest piece of all, weighing 200 pounds, fell some two miles further south. It is greatly to be regretted that so large a portion of this interesting and well authenticated fall should have been scattered and lost, only about forty pounds being now distributed among the various museums.

It was the report of this fall by Silliman and Kingsley that led Thomas Jefferson to make the remark—longsince and repeatedly denied—that it was easier to believe that two Yankee professors would lie than that stones should fall from heaven.

The well-known and now widely distributed Juvinas stone, which fell on June 15, 1821, has been the subject of numerous notices, from among which the following is selected for reproduction.[4]

We, Mayor of the Commune of Juvinas, Canton d'Antraigues, Arrondissement de Privas, département de l'Ardèche, report, that on the 15th of this present June, warned by a frightful noise, which was heard in our commune, and those which surround it, about three o'clock in the afternoon, we apprehended that some great and extraordinary event was about to effect a general destruction in nature, which obliged us successively to adopt regulations to satisfy us that no one in our jurisdiction had been the victim of the phenomenon which at first appeared to be inexplicable.

At length, after some days had elapsed, we were informed that a meteor, of which history furnishes no similar account, had burst upon the mountain de l'Oulétte, in the hamlet of Cros du Libonez, forming a part of our commune; and, according to Delmas, who is seventy years of age, its appearance was preceded and announced by two strong explosions, occurring nearly together, resembling the discharges of two large cannons, and followed by a frightful noise, that continued for more than twenty minutes, which spread alarm and consternation amongst the inhabitants, who believed they should be immediately swallowed up by some abyss ready to open under their feet; the flocks fled, and the goats and sheep collected in groups. At the same time

[4] *Thomson's Annals of Philosophy*, Vol. 20, 1822, pp. 73-74.

a black mass was seen coming from behind the mountain de l'Oulétte, describing, as it descended in the air, a quarter of a circle, and sinking into the hollow of the valley of Libonez.

This remarkable circumstance was scarcely perceived by any but children, who, less alarmed than more competent persons would have been, followed the direction, and have since pointed out the exact spot where this mass was swallowed up. Delmas adds that he heard in the air a confusion of voices, which he thought were, at least, five hundred devils, and whom he considers as the agents that transported this alarming phenomenon; at the moment he said to Claude Vaisse, one of his neighbors (who, like himself, was in the fields), "Do you hear; do you understand the language of all these people?" This person replied frankly, "I do not comprehend them"; but they were both persuaded that this mass was carried by infernal spirits. Delmas, for the latter reason, said to Vaisse, "We have only time for one act of contrition," cast his eyes on the ground, bowed his head, and tranquilly waited for death. Such was the consternation of all the witnesses of this terrible event that, according to their confession, they fancied they already saw the mountains rolling and heaped upon them.

The alarm was such, that it was not till the 23d of the month that they resolved to dig out this prodigy, of which they knew neither the form, the nature, or the substance. They deliberated for a long time, whether they should go armed to undertake this operation which appeared so dangerous; but Claude Serre (sexton) justly observed, that if it was the devil, neither powder or arms would prevail against him, that holy water would be more effectual, and that he would undertake to make the evil spirit fly; after which they set themselves to work, and after having sunk nearly six feet, they found the aerolite, weighing rather more than 202 pounds (English). It was covered with a black bituminous varnish, and some parts of it had a sulphurous smell. It was requisite to break it to get it out; there still remains a mass weighing about 100 pounds.

All the facts above stated are proved by all the inhabitants of the hamlet of Libonez; and especially Delmas, sen. and jun.; James and Claude Serre, Peter Charayre, John Chaudouard, Anthony Dumas and his child; and also Mary Ann Vidal, a young girl of about fourteen years of age; the two latter, who were less frightened, followed the direction of the stone, and actually found the place where it was buried. Concerning all which we have drawn up the present *proces-verbal* as a continuation of the history of these phenomena, a copy of which we shall send to M. the Prefect. (Drawn up and agreed upon at our house, the 25th of June, 1821.)

We, the Mayor of Juvinas, certify, that three days after, on the 26th of June, on visiting the place where this stone fell, another was

Meteoric Stone, New Concord, Muskingum County, and Guernsey County, Ohio

About fifteen minutes before 1 p.m., on May 1, 1860, the people of southeastern Ohio and northwestern Virginia were startled by a loud noise likened to the firing of heavy cannons, or to the explosion of a steamboat boiler. In all, twenty-three distinct detonations were heard followed by a series of rattling reverberations. The area over which these sounds were heard was not less than 150 miles in diameter. The cause of these sounds was the falling of a large number of stony meteorites upon an area about 10 miles long by 3 miles wide. The largest weighed 103 pounds. It struck the earth at the foot of a large tree and penetrated a hard clay 2 feet 10 inches. The entire weight of the stones recovered was about 770 pounds, distributed among thirty specimens

found at a short distance from it, which weighed about two pounds and a quarter; it was covered with a similar varnish, and entirely distinct from the first. (A true copy delivered by us, the Mayor of the Commune of Juvinas, the 3d of July, 1821.)

A mass of this stone weighing over forty-two kilograms is preserved in the Natural History Museum of Paris. The remainder in fragments of one gram and upward is scattered through the collections of over sixty museums and private collectors.

Continuing in chronological order, we have next to mention one of the most noted of American falls—that of Guernsey County, or New Concord, Ohio, in 1860. This was described by an eyewitness as follows:

On Tuesday, the first of May, at twenty-eight minutes past twelve o'clock, the people of that vicinity were almost panic-stricken by a strange and terrible report in the heavens, which shook the houses for many miles distant. The first report was immediately overhead, and after an interval of a few seconds was followed by similar reports with such increasing rapidity that after the number of twenty-two were counted they were no longer distinct, but became continuous, and died away like the roaring of distant thunder, the course of the reports being from the meridian to the southeast. In one instance three men working in a field, their self-possession being measurably restored from the shock of the more terrible report from above, had their attention attracted by a buzzing noise overhead, and soon observed a large body descending strike the earth at a distance of about one hundred yards. Repairing thither they found a newly-made hole in the ground, from which they extracted an irregular quadrangular stone weighing fifty-one pounds. This stone had buried itself two feet beneath the surface, and when obtained was quite warm. (See Plate 3.)

Accounts by other observers differ somewhat, but are not seriously contradictory. From all it would appear that the explosion was heard over an area not less than 150 miles in diameter; that the central point from which the sound emanated was near the southern part of Noble County, Ohio, and that the course was over the eastern end of Washington County, then across the interior of Noble County over the southwestern corner of Guernsey and the northeastern corner of Muskingum, with a direction of about forty-two degrees west of north, the stones reaching the ground at an angle of about sixty degrees. Over thirty pieces were found as a result of this fall, scattered over the neighboring farms, and weighing from less than one to 103 pounds, the total weight being estimated at upwards of 770 pounds or 350 kilograms. Of these the largest, the 103-pound mass, is in the museum of Marietta College, Ohio. Examples of this fall are to be found in upwards of fifty collections the world over, in fragments and complete individuals of all sizes up to the largest mentioned.

A shower of meteoric stones which fell near Hessle, near Upsala, Sweden, at 12:20 p.m., January 1, 1869, is worthy of note on account of the perfection of the record, as well as for the large number of individual stones and their somewhat unusual character. The fall is recorded as being accompanied as usual by a noise like heavy thunder, which was followed by a rattling sound as of rapidly driven wagons, ending with a musical, organ-like tone and then a hissing sound. The stones fell in great number and of varying weights, from less than one to 1,000 grams, the total weight being unknown, though 22,895 grams are distributed throughout the various museums and other collections of the world. They were strewn over an area lying thirty degrees east of south to thirty degrees west of north. Although so brittle as to be crumbled between the thumb and finger, but few were broken by force of impact, and one which fell on the ice rebounded without rupture. The most striking and unusual feature, however, was the presence of a coffee-colored carbonaceous matter in powder and in loose masses as large as the hand. This, though largely lost, was found to be made up of granules containing metallic particles which could be extracted with a magnet, leaving a residue consisting of: carbon, 51.6 per cent; hydrogen, 3.8 per cent; oxygen, 15.7 per cent; silica, 16.7 per cent; ferrous oxide, 8.4 per cent;

magnesia, 1.5 per cent; lime, 0.8 per cent; and soda, with traces of lithia, 1.5 per cent. Just what is the meaning of this is not yet apparent.

Beyond question the most remarkable meteoric shower, within the limits of the United States and within historic times, was that of Estherville, Emmet County, Iowa, which took place on May 10, 1879, at 5 p.m. The three largest masses weighed 92½, 170, and 500 pounds respectively, but there were in addition very many smaller pieces weighing from the fraction of an ounce to twenty-eight pounds each. The 92½-pound mass and some 600 of the smaller fragments are in the museum of Yale University.

This meteor was plainly visible in its flight through the air and was described as looking like a ball of fire with a long train of vapor or clouds of fire behind it. Its height above the earth when first seen was estimated at forty miles. The sounds produced by the explosions incidental to its breaking up were referred to as terrible and indescribable, as scaring cattle and terrifying people over an area of many square miles. The first explosion, for there were several, was louder than the loudest artillery; this was followed by lesser sounds, and then by a rumbling noise like the passage of a train of cars over a bridge. Approximately 116 kilograms from this fall are preserved in the British Museum, sixty kilograms in the University of Minnesota, fifty kilograms in the University of Paris, and forty-eight in Yale University. Over seventy of the collections the world over have representative specimens, of less, but varying weights.

Still another shower which is worthy of recall, even at the risk of wearying the reader, was that which took place near Holbrook in Arizona on July 19, 1912. At half past six in the afternoon, while it was still daylight, the meteor was heard passing over Holbrook, traveling almost due east with the usual sounds and leaving a train of thin smoky vapor. It made a very loud noise, lasting for half a minute to one minute, which was likened by witnesses to the rumbling of a rapidly driven farm wagon on a rough road, to escaping steam, to distant or long-continued thunder, or the booming of cannon. One large explosion was quickly followed by several smaller ones in rapid succession and stones began falling "raising many puffs of dust for a mile or more over the dry sand of the desert like those produced by bullets or the first drops of rain in a heavy shower. . . . The meteor was not seen in its flight, as it was too early in the evening for its luminosity to be visible."

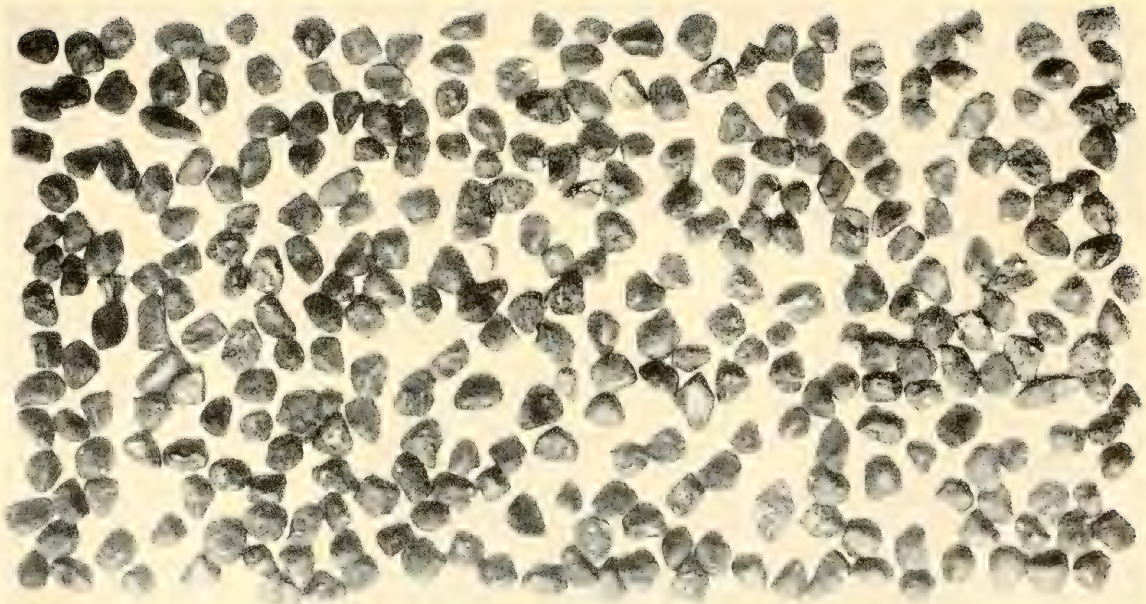
The stone was repeatedly shattered in its passage through the air and the surfaces of the fragments almost immediately fused again, so that each piece as found is covered with the black crust so characteristic of meteoric stones. The really extraordinary feature of the fall is the number of the pieces, of which there were estimated to be some 14,000, varying in size from that of a pea to five or six inches in greatest diameter. The accompanying plate (Plate 4) from the original description[5] shows the actual sizes and shapes of the smaller forms.

The two following falls stand in marked contrast with those just given, each yielding a single individual stone as a record of the event.

The first, that of a stone at Alfianello, Italy, fell on the afternoon of February 16, 1883, and though stated to have been accompanied by a loud detonation, gave no evidence of breaking into fragments. Owing doubtless to the time of day, no light accompanied the fall, but it left behind a trail of vapor comparable with the smoke from a rapidly moving locomotive. The direction of flight was from north-northeast toward the south-southwest. The stone penetrated the soil to the depth of a meter, shaking the ground like an earthquake, and, incidentally, frightened a nearby peasant into a fainting fit. But a single stone fell, which weighed approximately 260

[5] Wm. Foote, *Amer. Jour. Science*, Vol. 34, November, 1912.

PLATE 4



Showing some of the small sizes into which the Holbrook stone was broken

PLATE 5

Meteoric Stone, Allegan, Allegan County, Michigan

This stone, weighing about 70 pounds, fell on the morning of July 10, 1899, on the Thomas Hill, Saugatuck Road, near Allegan, Michigan. The mass came out of the northwest and buried itself about eighteen inches in a loose, sandy soil. The fall was accompanied by a loud report followed by a rumbling and a hissing sound. The stone was dug up a few minutes after the fall and is stated to have been too hot to handle. The characteristic black crust shows well-marked lines of flow and fusion structure, but the mass could not have had a high temperature on striking the ground as the grass roots adhering to it show no signs of charring. The ash-gray groundmass is exceedingly friable and is made up of an agglomerate of particles of olivine, enstatite, chromite, nickel-iron, troilite, and schreibersite. Its structure is chondritic and characterized by the large size and spherical perfection of many of the chondrules kilograms (572 pounds) though it quickly became broken up and the pieces scattered. About one-fifth of the original weight has been preserved, the largest piece, of 12,757 grams, being now in the museum at Berlin.

The Allegan, Michigan, fall, on the morning of July 10, 1899, was also of a single stone. (Plate 5.) This was stated by observers to have come from the northeast, and to have buried itself in the sand to a depth of eighteen inches, striking within ten rods of a man working in the fields.

Attention was first attracted to it by a cannonlike report, followed, as the stone came nearer, by a hissing sound as of an engine blowing off steam. When first seen in the air it had the appearance of a black ball about the size of a man's fist, and as it passed overhead it was described as leaving a "blue streak" behind, but no light. It was dug from the ground but a few minutes after falling and was said to be too hot to hold in the hands, and that the sand was hot around it. Nevertheless, shreds of dead leaves and grass which became closely compacted against its surface on striking, were not charred in the least. It would seem probable that here, as in many other cases, it was expected the stone would be hot, hence it was so reported.

This stone, which weighed approximately seventy-five pounds, was badly shattered in falling. The main mass is among the collections of the National Museum.

It will be noted that all the falls thus far described yielded stones or stony irons. Of all the known *iron* meteorites, but seventeen were seen to fall, and of these only that of Mazapil, Mexico, need be given in detail. The account is that of one Eulogio Mijares, a ranchman living at Mazapil. This fall is of special interest, having taken place during one of the periodic meteor displays.

It was about 9 o'clock in the evening (November 27, 1885) when I went to the corral to feed certain horses, when suddenly I heard a loud sizzing noise, exactly as though something red-hot was being plunged into cold water, and almost instantly there followed a loud thud. At once the corral was covered with a phosphorescent light and suspended in the air were small luminous sparks as though from a rocket. I had not recovered from my surprise when I saw this luminous air disappear and there remained on the ground only such a light as is made when a match is rubbed. A number of people from the neighboring houses came running toward me and they assisted me to quiet the horses which had become very much excited. We all asked each other what could be the matter, and we were afraid to walk in the corral for fear of getting burned. When in a few moments we had recovered from our surprise we saw the phosphorescent light disappear, little by little, and when we had brought the lights to look for the cause, we found a hole in the ground and in it a ball of fire (*una bola de lumbre*). We retired to a distance, fearing it would explode and harm us. Looking up to the sky we saw from time to time exhalations or stars, which soon went out, but without noise. We returned after a little and found in the hole a hot stone, which we could barely handle, and which on the next day looked like a piece of iron; all night it rained stars, but we saw none fall to the ground as they seemed to be extinguished while still very high up.

In view of what has just been said concerning the temperature of the Allegan meteorite, attention should be called to the fact that this was an iron. The reason for this remark will appear later.

The most remarkable of meteoric *finds* within the limits of the United States, or indeed in the world,[6] is that of Canyon Diablo, in Arizona. At and about a point between Winslow and Flagstaff, in Yavapai County, and south of the Santa Fé railroad, several thousand pieces of metallic (meteoric) iron, in weight from a gram to 1,000 pounds, have been found, for the most part scattered over an oval area some 3½ by 4½ miles, though one of the largest masses was found eight miles to the eastward. The total weight of all the material will never be accurately known, but it must lie somewhere between fifteen and twenty tons. Nothing, even by tradition, is known regarding the date of fall. So large a quantity of meteoric material scattered over the plain would in itself excite

[6] Unless certain recent newspaper accounts of an occurrence in Siberia should prove correct.

PLATE 6

Meteoric Iron. Fell at Mazapil, Mexico, Nov. 27, 1885. Weight about 4 kilograms or 8.8 lbs. Note the beautiful sculpturing or piezoglyphs. For description of fall see p. 21

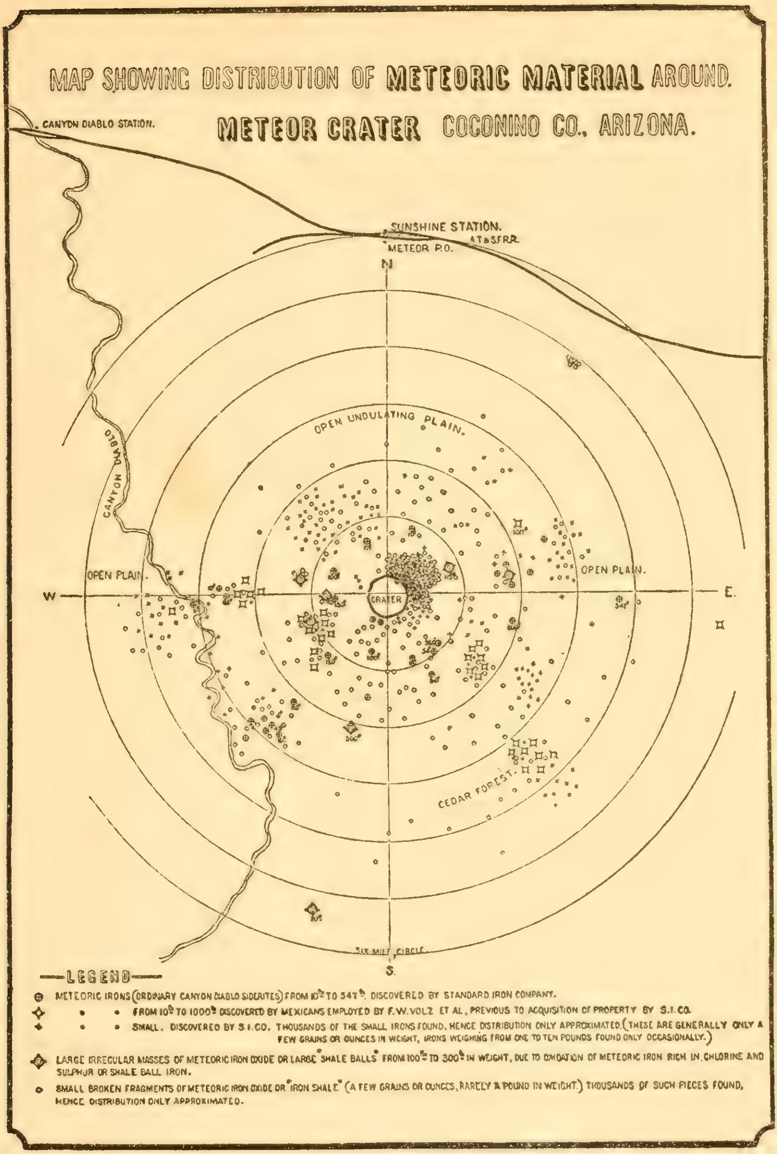


FIG. 2. Area of distribution of Canyon Diablo Meteorite.
(After D. M. Barringer)

interest and curiosity and taken in connection with the existence, close at hand, of an immense crater-like depression, early gave rise to the theory that the crater itself (Plate 7) was due to the impact of an enormous meteorite. This occurrence has often been described[7] but is of sufficient interest to merit additional notice here. The region is that of an elevated, nearly level, sandy plain the floor of which is composed in the main of a buff-colored arenaceous limestone which is capped here and there by residual patches of red sandstone and underlain by a highly siliceous, friable sandstone. The crater-form depression is some 4,000 feet across and 600 feet deep, the original depth having been greatly lessened by *débris* blown in from the surrounding plain. The crater rim is composed of the upturned, crushed, broken, and bent beds of sand and limestone overlain by large blocks, sometimes thousands of tons in weight, of the same material thrown out from the crater itself. In addition are enormous quantities of finely pulverized siliceous sand which has plainly been derived from the sandstone by the shock of an explosion or the impact of some descending body. There are also, intermingled with this, occasional blocks of siliceous pumice which apparently owe their origin to the fusion of the same sandstone. So convincing are these facts that extensive drilling and tunneling have been undertaken in the hope of finding a buried monster meteorite.

Though the illustrations given can leave no present doubt as to the ultraterrestrial origin of meteorites, it is but natural that there should at first have been much skepticism both in the popular and scientific mind regarding the possible fall of stones from empty space. So great was this skepticism that, as stated by E. F. F. Chladni, of Vienna, in his *Feuer-Meteore* published in 1819, the examples preserved in the public museums were hidden or

[7] Meteor Crater in Northern Central Arizona, by D. M. Barringer, and others by the same author. Also The Meteor Crater of Cañon Diablo, etc., by Geo. P. Merrill, *Smithsonian Misc. Coll. Q. Issue*, Vol. 50, Pt. 4, 1908.

PLATE 7

Meteor Crater, Arizona. From a photograph. (Courtesy of the U. S. Army Air Service)

discarded, the custodians fearing to make a laughing-stock of themselves through acquiescing in the possibility of their extraterrestrial origin. As long since noted by Izarn, it was those trained in power of observation and able to realize the improbabilities of such an occurrence that were slowest to accept the idea of an ultraterrestrial source. The Swiss geologist, J. André de Luc, is quoted as saying that though he should see one fall he would not believe it.[8]

The fall in 1492 of the meteoric stone at Ensisheim, an account of which is given on page 7, would seemingly have been sufficiently convincing, but even as late as 1772, a committee, one of whom was the celebrated chemist, Lavoisier, presented to the French Academy a report on the examination of a stone seen to fall at Lucé four years previously. In this they took the ground that the supposed sky stone was but an ordinary terrestrial rock that had been struck by lightning.

As early as 1794, Chladni, referred to on the previous page, had called the attention of the scientific world to the fact that several masses of iron had in all probability come to our earth from outer space. He referred especially to the now well-known Pallas stony-iron, which was found by a Cossack in 1749, among schistose rock, and in the highest part of a lofty mountain near Krasnojarsk in Siberia. It was regarded by the native Tartars as a holy thing fallen from heaven, which fact would certainly seem to indicate that it was seen to fall. Chladni argued that this iron could have been formed only under the influence of fire. The absence in the vicinity of scoriae, the ductility of the iron, the hard and pitted surfaces, and the regular distribution of the included olivine, to his mind precluded the idea that it could have been formed where found, or by man, electricity, or an accidental conflagration. Hence, he inferred that it had been projected from a distance, and, as there were no volcanoes

[8] "Ich habe es gesehen, ich glaube es aber doch nicht."

known to eject iron, and as, moreover, there were no volcanoes in the vicinity, he was compelled to look for an extraneous source, and to regard it as actually having fallen from the sky. Incidentally, he argued, the flight of such a body through the atmosphere would give rise to all the phenomena of the fireball or shooting star.

It was, as has been remarked, as if to direct attention to Chladni's work that there occurred during this same year an observed shower of meteoric stones near Siena, Italy. In December of the following year, also, a 56-pound stone fell out of a clear sky almost at the feet of a laborer near Wold Cottage in Yorkshire, England, and again in 1798, under similar conditions, many stones fell at Krakhut, near Benares, in India.

Notwithstanding all these and numerous other recorded occurrences, the scientific minds of the day remained unconvinced, or only partially convinced. Fortunately there occurred in broad daylight about this time (April 26, 1803) a shower of upward of 3,000 stones in the neighborhood of Laigle, France, already mentioned. The circumstances of this fall were thoroughly investigated under the auspices of the French Academy of Sciences (see page 11). The report, covering over forty quarto pages, was of so conclusive a nature as to forever set aside all doubts as to their ultraterrestrial nature and probable source.[9]

[9] Nevertheless there remained doubters. An amusing illustration of the varying opinions on the subject, as well as of the condition of chemistry and power of observation at the time, is given by a writer in *Tilloch's Magazine* (Vol. 46, 1815). "Why," he writes, "do men of science persist in saying that meteoric stones fall from the heavens, as if planets could contain within their bodies a force of projection superior to their force of gravity, and capable of pushing their matter beyond the limits of their attraction, or as if masses so enormous could be formed in the air; where, besides, there exists no base of bodies as in the azote, without an extrication of air, felt over the whole globe, being the effect of it. . . . The phenomenon always takes place in open grounds and where without finding much resistance the stone may sink into the ground; therefore they do not fall, but are formed of the substance of the soil, which the lightning puts in a state of fusion. If this substance be pure silex the stone forms rock crystal rounded like flint. If it be a mixed soil, the flux is also mixed and some of its oxides may, by the force of the fire be reduced, nay it is even compounded into metal."

Portrait of E. F. F. Chladni. From an engraving in Flight's *A Chapter in the History of Meteorites*

PLATE 9

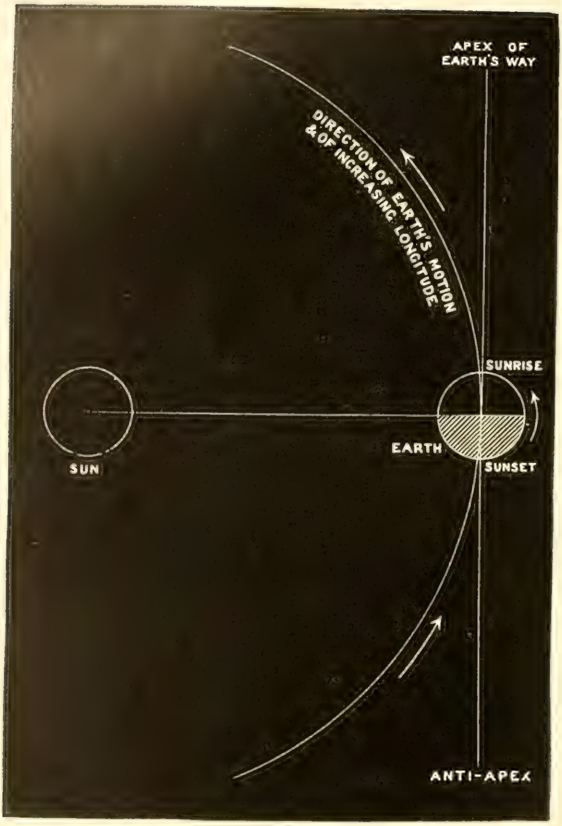


Diagram of earth and sun

CHAPTER II

PHENOMENA INCIDENTAL TO FALL

In the accounts given in the previous chapter it will be noted that much stress is laid upon the phenomena of sound and light attendant upon the fall of a meteorite. That these phenomena are due wholly or in part to the rapid passage of the bodies through the air and the resistance encountered would seem unquestioned. It will be well, then, to give this phase of the subject a share of our attention.

The astronomer Newton calculated the speed of the fire-balls which passed over the Ohio and Mississippi valleys in August, 1860, as thirty to thirty-five miles per second, and it is stated that the stone of Stannern, Moravia, which fell in 1808, came into the earth's atmosphere with a velocity of forty-five miles per second.

That there may be actually a considerable variation in these velocities will be readily apparent when consideration is given to the direction of the flight with reference to that of the earth, as shown in the accompanying diagram. (Plate 9.) If a body is following the earth in its course about the sun the apparent speed will be but differential. Thus a meteorite with a velocity of twenty-five miles per second overtaking the earth traveling at the rate of nineteen miles per second, would enter our atmosphere with an initial speed of but six miles per second. In the case of a meteorite pursuing a retrograde course, conditions would be greatly exaggerated. With the same velocity it would meet the earth traveling in the opposite direction, and hence would enter our atmosphere with an initial velocity of forty-four miles per second. This is, however, far above the speed with which the meteor actually reaches the earth, atmospheric pressure so far retarding it that it may fall with little if any speed higher than that imparted to it by gravity. In this connection the following table by G. von Niessel, showing the height above the earth at which certain meteorites have lost their initial velocity, is of interest:

Von Niessel's Table

	Miles
Homestead	2.30
Krähenberg	5.09
Mocs	5.21
Weston	6.89
Knyahinya	7.38
Braunau	9.19
Orgueil	14.28
Pultusk	25.76
Hraschina	29.00

From whatever direction the meteorite comes, it is meteoric *stone* which has come under the writer's observation is that of Knyahinya, Hungary, as described by Haidinger. In this instance a 660-pound stone (Figure 3), views once held concerning the possible identity of the shooting stars and meteorites.

The astronomer Herschel calculated the velocity of the Yorkshire, England, meteorite at the time it reached the ground as but 412 feet a second. The Guernsey County, Ohio, stone was estimated to have reached the earth while traveling at a speed of three or four miles a second; that of Weston, Connecticut, while at a height of some eighteen miles, was estimated by Professor Bowditch to have a velocity of three miles a second. The evidence of speed afforded by the impact of actual falls is extremely contradictory. Obviously a stone falling from a great height would, if gravity alone were considered, reach the surface with the greatest force of impact. Nordenskiöld states

View of a portion of the moon's surface. Compare with view of Meteor Crater, Plate 7

that in the case of the Hessle fall, stones so friable as to be readily broken if simply thrown against a hard surface, were not broken or even scarred on striking the frozen ground. Stones weighing several pounds which struck on ice a few inches in thickness rebounded without breaking the ice or being themselves broken. The 70-pound stone that fell at Allegan, Michigan, in 1899, penetrated the sandy soil to a depth of about eighteen inches and was itself considerably shattered. Like that of Hessle, this was an unusually friable stone. It is evident that its speed did not equal that of a projectile from an old-time piece of heavy ordnance. The 260-pound stone that fell at Ensisheim, Germany, in 1492, is reported to have buried itself to a depth of five feet. The greatest depth of penetration of a meteoric *stone* which has come under the writer's observation is that of Knyahinya, Hungary, as described by Haidinger. In this instance a 660-pound stone (Figure 3), striking the ground at an angle of some twenty-seven degrees from the vertical, penetrated to a depth of eleven feet. The hole was nearly circular in outline and fragments from the interior were thrown back and scattered to a distance of some 180 feet (*dreizig Klafter*). The stone was found broken in three pieces and the earth beneath it compacted to a stony hardness. The 71-pound mass of the Hraschina *iron* is stated to have buried itself to a depth of eighteen feet. On the other hand, still heavier

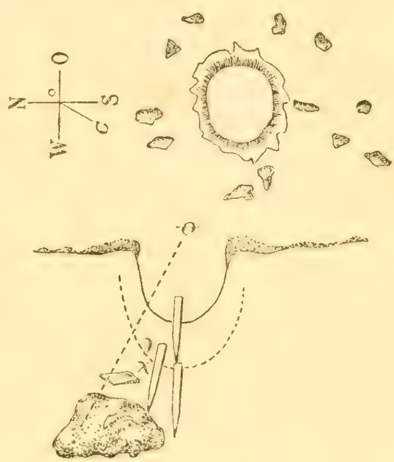


FIG. 3. Diagram of fall of meteorite at Knyahinya, Hungary

masses have been found under such conditions as to lead one to infer that they scarcely buried themselves.

Peary's giant Cape York iron, weighing 37½ tons, was found only partially covered, but as it lay on a bed of gneissic bowlders, this is not strange. It should be remarked, however, that an examination of the iron reveals no such abrasions of the surface as might be expected had it fallen with a speed of whole miles per second, nor, indeed, any abrasions whatever that can be ascribed to such a cause. It is, of course, possible that this fall took place when the ground was deeply covered with ice and snow, and its speed was thus checked before coming in contact with the stony matter.

The Willamette, Oregon, iron, weighing 15.6 tons, seemingly without question lay as it originally fell, and in a region of no appreciable erosion—rather one of organic deposition—for it was found lying in a primeval forest; yet the mass was scarcely buried, a small projecting portion leading to its discovery.

The Bacubirito, Mexico, iron, weighing, at a rough estimate, twenty tons, lay in a soft soil but little below the general surface of the field around it.

Although so seemingly ineffective, it is nevertheless permissible, without being sensational, to consider for a moment what might be the result of meteoric bombardment were not our earth protected by its armorplate of atmosphere. Probably the surface of the moon, spotted over by deep pits, offers the best illustration of the possible consequences.

The hissing sounds so frequently reported in meteorite falls may seemingly be ascribed to speed alone, as in the case of a rifle ball or other high-power projectile; the thunderlike sounds to the same cause as those of ordinary thunder—the collapsing of an atmospheric vacuum, as caused by lightning. The crackling and crashing sounds are due largely to the breaking up of the meteorite during its descent, a feature itself due to the pressure of the atmosphere and to the expansion of the exterior shell through heat produced by the same cause. The astronomer Herschel has stated that at the height of twelve miles a velocity of twenty-seven miles per second would produce a pressure of a little over 10,000 pounds per square inch. While an iron meteorite might withstand this, a stone would almost certainly be crushed. This would account for so many stony meteorites coming to us in the form of showers of fragments.

The astronomer Young has stated that the quantity of heat evolved in bringing to rest a body which has a velocity of forty-two kilometers or twenty-six miles a second is vastly more than sufficient to fuse it, even were it composed of the most refractory material. The effect, indeed, is the same as though the meteor was immersed in the flame of a blowpipe having a temperature of many thousands of degrees. With a moving body having a velocity of about 1,500 meters per second, the temperature would be raised to about that of redness. With a speed of twenty or thirty miles per second, the meteor would be acted upon as if immersed in a temperature of several thousand degrees, and the liveliest incandescence would result, the meteor becoming fused and catching fire on the immediate surface and being perhaps almost entirely consumed. H. E. Wimperis, indeed, has calculated that, owing to this cause, no iron less than ten pounds in weight on entering the atmosphere would survive. That the meteors of different showers exhibit these described features with different degrees of intensity arises, according to the astronomer Chambers, from the fact that their apparent speed depends in a great measure upon the angle with which they meet the earth, as already noted.

Thus the meteors of November 13 (Leonids) are moving in a direction opposite to the earth; hence their veolcity is very great, being about forty-four miles per second. But the meteors of November 27 (Andromedes) are moving in nearly the same direction as the earth, and hence have to overtake us, so that they apparently move very slowly, their speed being only eleven miles per second. The Leonids above referred to, together with the Perseids of August 10 and the Orionids of October 18–20, are good examples of the swift-moving meteors, and they are almost invariably accompanied by phosphorescent streaks. The slow meteors, of which the Andromedes are a type, throw off trains of yellowish sparks.[1]

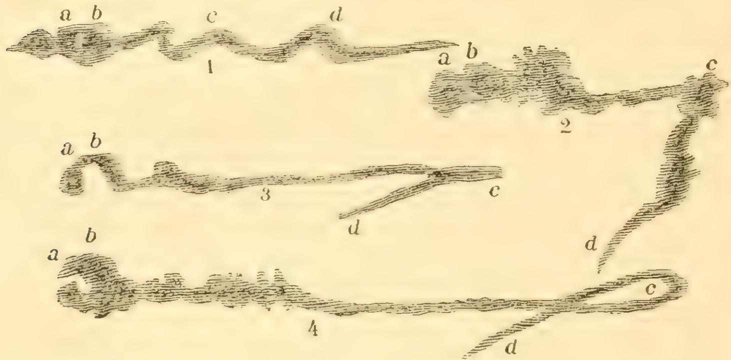


FIG. 4. The afterglow of meteorites

The pressure of the air in any case is such that the fused and burning materials are immediately stripped off the outer exposed portions, forming the trail of light, so conspicuous a feature of the early part of the phenomenon. This, of course, does not apply to the so-called "afterglow" (Figure 4) which sometimes remains in the air for several minutes after the meteorite has passed and which is commonly believed to be due to phosphorescent nitrogen and perhaps other gases formed by the heat of the passing body.[2] Only on the rear, if at all, does the fused material accumulate to an appreciable thickness. As the meteorite

[1] Handbook of Descriptive and Practical Astronomy: Sun, Planets, Comets, 4th ed. Vol. 1, p. 635.

[2] "The motion of the meteor through the atmosphere produces an exceedingly high temperature and may bring about chemical or physical changes in the composition of the atmosphere in the track of the meteor, which on reverting to its original state gives out a phosphorescent glow, or the surrounding air may be highly ionized by the vaporizing meteor so that electrical discharges take place great enough to produce an afterglow like that following the electrodeless discharge." C. C. Trowbridge, *Proc. Nation. Acad. Sci.*, Vol. 10, 1924, p. 38.

Fall of a meteorite at Montpreis, in Styria, on July 31, 1859. (From *L'Astronomie*, Vol. 2, 1883)

approaches the earth the speed is gradually checked, and by the time it is reduced to two miles a second, the heat generated is no longer sufficient for fusion, the remaining thin coating of molten material quickly congeals as a black crust, and the stone drops to the earth no longer luminous and doubtfully even hot. The word *doubtfully* is used here intentionally, for reports on this phase of the subject are very contradictory. Before giving the evidence pro and con, the reader is, however, asked to consider the probabilities.

As is well known, the temperatures at comparatively short distances above the earth are very low; even at the slight altitudes reached by flying machines it is "freezing cold," and astronomers and physicists tell us that the cold of space is that of "absolute zero." Now the meteor has been wandering through this space for untold years and but for absorption of heat from the sun on its way to earth must in time acquire a like temperature. The problem of determining the probable temperature of falling bodies in space is extremely complex and cannot be touched upon here. Reference may again be made to the calculations of Prof. H. E. Wimperis, who, from a study of the conditions of flight of a meteorite compared with artillery shells, reached the conclusion that an iron meteorite of ten to twenty pounds in weight would have at the center, on reaching the earth, a temperature not far from that of liquid air ($-140°$ C. or $-220°$ F.). Prof. A. T. Jones, in a recent reconsideration of the problem, arrived at the conclusion that when a meteorite falls during the daytime, its temperature is probably not far from $0°$ C. when it enters the atmosphere of the earth. Widely variant as these estimates seem, they are sufficient to show that whatever apparent heat the stone or iron possesses at the time of its fall must have been acquired wholly through atmospheric pressure during the few last brief seconds of its flight. But, as has been stated, the heated surface of the flying body is stripped off almost as fast as formed, and never, so far as shown, penetrates to any appreciable depth. Hence, it seemingly follows that in the case of poor heat-conducting substances like meteoric stones, the heat at the time of their reaching the ground must be practically negligible, differing little if any from that possessed at the time they entered the atmosphere, let this be 0° C. or −140° C., as the case may be.

Actual testimony, in print or otherwise, is quite contradictory, and allowance must be made for the fallibility of the human mind as so frequently exemplified in the courts, particularly in the case of unusual or startling phenomena, and for a natural predilection on the part of an individual to report an object as in the condition in which he has been led to expect to find it.

Poggendorff, in his *Annalen* for 1838, records the setting of fires by meteorites in 1761 at Burgoyne, France, Bury St. Edmunds, and other localities. According to Haidinger, some stones which fell in Styria in 1859 continued in a state of incandescence for from five to eight seconds, and for a quarter of an hour were too hot to be handled without burning. Beinert, in his account of the Braunau iron (1847), states that for six hours it remained too hot to be handled, as did also that of Mazapil, Mexico (1887), referred to on page 21. In an account of the fall of an iron meteorite in Mogul, India, it is stated that the earth for a distance of ten to twelve yards about the spot was "burnt to such a degree that not the least trace of verdure or blade of grass remained," and that on attempting to dig it up "the heat was so violent that one might have supposed it to have been from a furnace, but became cold after some time." Unfortunately there are indications of exaggeration in these accounts such as to render it unsafe to rely upon them implicitly.[3] The iron which fell at Pitts, Georgia, in 1921, is stated to have

[3] The writer has actually had bowlders from the glacial drift sent him, with similar statements.

been still warm when dug up a few minutes later, but not red-hot, as first reported. Taken in connection with that of the Mazapil fall this account would seem to lend probability to the suggestion elsewhere made that iron meteorites reach the earth while traveling at a higher rate of speed and, being better conductors, become more highly heated than do the stones. The Dhurmsala stone of 1860 is stated to have been intensely cold when picked up immediately after falling, frost forming on its surface. The stone of Alfianello, Italy, is likewise reported by Bombicci to have been extremely cold internally,[4] as was also that which fell at Olivenza, Spain, in 1924. A similar statement regarding the Colby, Wisconsin, stone of 1917 has been made, while the Tilden, Illinois, stone of 1924 is reported as "noticeably cold" when exhumed almost immediately after falling.

The reports of the setting of fires by falling meteorites must be taken therefore with some degree of allowance. The writer considers it more than probable that, were it possible to reinvestigate the early reports, they would be found largely erroneous. In the cases of the Allegan, Holbrook, Winnebago, and Rose City falls, the stones struck on dried grass, which, though pressed closely against the surfaces, was not charred in the least. Indeed, one of the Winnebago stones fell on a stack of dry straw without igniting it.

Naturally the possibility of injury to human beings and other animals by falling meteorites has often been discussed, and several instances are recorded, mostly as having occurred during the sixteenth and seventeenth centuries. It must be confessed, however, that owing to the lack of confirmation by writers after the first momentary period of excitement had subsided, there is here also very grave doubt as to the truth of the occurrences; certainly they cannot be accepted as matters of

[4] "Auche Laerolite di Alfianello si trovo' freddissimo nelle superficie di rottura, al momento dello scavo."

fact. Nevertheless, it will be well to recall a few of the reported cases of this nature and to give them whatever credence they seem to deserve.[5]

Bigot de Morogues, in his *Memoirs* published in 1812, quotes the account of two sailors who in 1654 were killed by the fall of a meteorite while standing on the bridge of a vessel sailing between Japan and Sicily. He mentions, too, the fall of an iron at Lessay near Coutenes, France, in 1737, by which animals were killed and many buildings fired.

Some accounts of the fall at Barbotan, France (1790), state that a stone fifteen inches in diameter broke through the roof of a cottage and killed a herdsman and a bullock; subsequent accounts, while confirming the fall through the roof, make no mention of the killing.

Mondegenitus states in his *Life of Marcus Aurelius*, that during the reign of the Emperor Vallatian such a copious shower of stones fell in Constantinople that it killed not only several people but most of the cattle in the fields. Through lack of confirmation this is regarded as altogether improbable.

In the *London Philosophical Magazine* of 1811 is an extract from a writer in Futty Ghur (Fettehghur?), India, in which occurs the following:

> I open this letter to let you know of a very odd circumstance which happened a few days ago, viz., a large ball of fire fell from the clouds which burnt five villages, destroyed crops and some men and women. The ball is now still to be seen; it is hard as a stone. This happened near Shahabad, across the Ganges . . . I have heard nothing further about this but a vague report.

Vague indeed it must have been since there is no record of any meteorite having fallen at this locality.

T. F. Phipson, in his book on meteors (p. 85), mentions on the authority of a Carthusian monk the fall of more than a thousand stones at Crema near Milan, Italy, in 1511. The largest of these weighed 120 pounds.

[5] Which is very little.

PLATE 12

Meteoric Iron, Casas Grandes, Chihuahua, Mexico

This iron is supposed to be the mass found in 1867 in an old tomb in the ruins of the Montezuma Casas Grandes (large houses), in Chihuahua, Mexico. When found it was "carefully and curiously wrapped with a kind of coarse linen, similar to that with which the Egyptians inclose or wrap their mummies." "Twenty-six yoke of sturdy oxen were mustered and as many or more strong log-chains, and, with this force and tackle the monster meteorite was hauled from there to the modern town of Casas Grandes." Some doubt has been cast upon the identity of the iron here shown and that above described by the somewhat conflicting statements regarding the weight and size. The iron weighed before cutting 3,407 pounds. It was cut in order to give a flat surface for etching, to show its crystalline structure which is octahedral. Nothing is known concerning the date of its fall

Birds and sheep were reported killed by this fall and also one human being, a Franciscan friar.[6]

Even as late as 1838 we have an account of the fall of an immense quantity of stones in the Province of Ceará in Brazil, in which the roofs of dwellings were penetrated and many animals killed, although no human life was lost. Here again it should be noted that subsequent accounts by Derby and others make no reference to such an incident nor is there any record of such a fall. It is a fair assumption that every one of these recorded cases simply illustrates the tendency to exaggerate so characteristic of the human species during periods of momentary excitement. That the fall of a large meteorite *might* inflict serious injury is unquestioned. The possibilities of such an occurrence are, however, so slight as to be almost negligible.

That many individuals ascribe to meteorites the shower of stones which destroyed the enemies of Joshua at Beth-horon is well known, but needs no comment.

It is but natural that in the early days of superstition and occasional idolatry the phenomena of a falling meteorite should have been considered due to supernatural causes, and the body itself, if found, regarded with more than usual fear or veneration as the case might be. Out of the many instances of this kind that might be mentioned, but few are worthy of repetition here.[7] It is stated that a stone which fell in ancient Phrygia, in Asia Minor, about 200 B.C., was worshiped by the Phrygians and Phœnicians as Cybele, the mother of the gods. Another, of which the history goes back far beyond the seventh century A.D., is the sacred *Black Stone* of the Mahommedans, still preserved at Mecca, where it is built into the southeast or "black" corner of the Kaaba

[6] The same story is repeated by Humboldt in his *Cosmos*, Vol. 4, Bonn edition. None of the material of this fall has been preserved, and as a like occurrence was reported in the same locality in 1650, we may well feel justified in doubting both.

[7] See The Worship of Meteorites, by Hubert A. Newton, *Amer. Journ. Sci.*, Vol. 3, 1897, pp. 1–14.

and revered as one of the holiest of holy relics. The Anhadra, India, pallasite, which fell as recently as 1880, is stated to have been immediately taken in possession by Brahman priests who erected a brick temple over the spot. People flocked to it in large numbers, bringing offerings of food and flowers and affording a considerable annual income to the wily promoters.

Kidd in his work on *Savage Childhood* (London, 1906) states: That in the case of a new born Kaffir baby, the child is made to inhale the smoke from a burning mixture of various compounds, the most important ingredient of which is a meteorite which has been well burned and then ground to a fine powder. The Kaffirs think that this substance has the power of closing the anterior fontanelle of the baby's skull, of strengthening, and of making firm the bones of the skull, of imparting vigor to the child's mind, and of making the infant brave and courageous. The strength of the meteorite is thought to enter into the child's whole system.

The great Casas Grandes iron (Plate 12), in the National collections at Washington, was found in an ancient Mexican ruin, swathed in mummy cloths in a manner to indicate that it was held in more than ordinary veneration by the prehistoric inhabitants. The Wichita, Texas, iron, known to the Indians of that region for many years, is said to have been set up by them as a kind of fetish, or object of worship or veneration, as foreign to the earth and coming from the Great Spirit. Meteoric iron has also been found upon a brick altar in prehistoric ruins in Ohio, and it is recorded that a stone weighing about a pound, that fell in East Africa in 1853, was secured by the natives, anointed with oil, clothed and decorated, and finally installed in a temple especially prepared for it. Concerning two Japanese meteorites, it is stated by a writer in the *Transactions of the Asiatic Society* that:

They used formerly to be among the offerings annually made in the temple of Ogi to Shokujo (*Tanabata tsu me*) on her festival, the seventh

PLATE 13

The Cape York Meteoric Iron. Weight 37½ tons. (Courtesy of the American Museum of Natural History, New York)

day of the seventh month. There is no mention of these having fallen on this day in the year, but they were connected with her worship by the belief that they had fallen from the shores of the Silver River, Heavenly River, or Milky Way, after they had been used by her as weights with which to steady her loom.

In the 1830 edition of the *Edinburgh Encyclopedia*, de Guignes relates that a star fell to the ground in China and was converted into a stone, an event which created an extraordinary sensation. The inhabitants of the district, willing to convey a moral lesson to their unpopular emperor, caused these words to be engraved on the stone: "Chi-Hoang-Ty draws near to death and his empire will be divided." As a punishment the emperor condemned the inhabitants to death but died himself the following year, and his empire was divided into several kingdoms.

Not only the actual falls but also the intangible shooting stars excited feelings of unrest in superstitious minds. The oft-quoted and immortal Pepys, under date of March 21, 1667, wrote:

> All the town is full of the talk of a meteor, or some fire, that did on Saturday last fly over the city at night, which do put me in mind that, being then walking in the dark an hour or more myself in the garden after I had done writing, I did see a light before me coming from behind me, which made me turn back my head: and I did see a sudden fire or light running in the sky, as it were, toward Cheapside-ward, and it vanished very quick, which did make me bethink myself what holyday it was, and took it for some rocket, though it was much brighter: and the world do make such discourse of it, their apprehensions being mighty full of the rest of the city to be burned, and the Papists to cut our throats.[8]

[8] It is not strange that in the early days the fall of one of these bodies should be considered of sufficient significance to demand some form of public recognition, even if not of reverence. Such a feeling, according to Brezina (*Proc. Amer. Philos. Soc.*, Vol. 43, No. 176, 1904) found expression about 400 or 500 B.C. in the striking or casting of metal (bronze, silver, or gold) *betyls* or coins, presenting "as a common feature the likeness to conic stones, or obelisks, or to archaic, half-conic simulacra, so that it came about that similar representations of unknown origin were likewise supposed to represent sacred meteorites." Brezina lists and figures forty-one such coins which he classes as (1) betyls representing stones fallen from heaven, and (2) betyls accepted by analogy to represent meteorites. Their authenticity is not, however, generally recognized.

But if the fall of these comparatively small bodies, weighing at most but a few hundred pounds, is accompanied by phenomena so extraordinary as to impart veneration or terror to man and beast over wide areas of country, what must have been the effect produced by the fall of such giants as those of Cape York, Greenland; Bacubirito, Mexico; Willamette, Oregon; or that which formed the Canyon Diablo crater. Fortunate it may be for the individual that he was not a nearby witness of their terrific display, but it is nevertheless to be regretted that their fall was unrecorded, and perhaps unseen as well. The closest imaginable approximation to such a possible display of which we have record, is that of the great meteor of 1860 which left no tangible record of its brief excursion into our atmosphere. The following is abridged from an account of this remarkable visitor, given in the *American Journal of Science*, Volume 30, 1860. The meteor was traveling from north-northwest to south-southeast, or in a direction from Lake Michigan to the Gulf Stream. It was visible over an area at least 1,000 miles in length and 700 or 800 in width. The time of its passage, according to the most reliable witnesses, was estimated at twenty to forty-five seconds, with an actual velocity of some twenty-six miles per second. Its height when seen over Lake Michigan was estimated at 120 miles. This was gradually reduced until over Long Island it was but forty-two miles.[9] The actual dimensions of the luminous mass were from one-third to one-fifth of a mile. When first seen it was in the form of a more or less elongated single body, gradually increasing in brilliancy and throwing off sparks and flashes of light. When about over Elmira, New York, an "explosion" took place and the meteor separated into two principal portions with many subordinate fragments,

[9] In the *Report of the Smithsonian Institution* for 1868 it is stated that the velocity when nearest the earth was 9.76 miles per second, and that its nearest approach to the earth was at about the middle of New York State, where its altitude was 39.19 miles.

PLATE 14

The Willamette Meteoric Iron. (Courtesy of the American Museum of Natural History, New York)

all of which continued on their course, scattering sparks along the track, until at a point south of Nantucket where a second explosion occurred. Shortly after this the meteor passed from view, probably falling into the Atlantic, although it is doubtfully possible that it passed again out of our atmosphere, and went on its way once more with an orbit considerably disturbed and a constitution considerably shattered by its close proximity to the earth.

CHAPTER III

AREAS OF DISTRIBUTION

In many cases of meteoric showers like those mentioned on previous pages, the individual pieces are distributed over oval areas of considerable extent, the longer axes of which are in the direction of flight, the heavier masses being carried the greater distances. The Holbrook, Arizona, shower of July 19, 1912, was estimated by W. M. Foote to comprise over 14,000 individuals weighing from one-tenth to upward of 2,000 grams each, which were scattered over an ellipsoidal area about one-half of a mile wide and three miles long. The Knyahinya, Hungary, fall comprised over 1,000 individuals; that of Laigle, France, between 1,000 and 2,000; and that of Pultusk, Russia, has been estimated to have comprised 100,000. The Hessle, Sweden, fall, according to Nordenskiöld's map, must have been scattered over an area some two miles wide and ten miles in length, in a northwest and southeast direction, while the shower of Mocs, Transylvania, comprising 3,000 or, as estimated by Brezina, 100,000 individuals, was spread over an area three miles in length. The celebrated Coon Butte, or Meteor Crater, find near Canyon Diablo in Arizona, comprised many thousand individuals weighing from one gram to 500 kilograms, scattered over a known area of some four miles radius about the crater (Figure 2), the smaller of these being plainly oxidation residues and the total weight probably twenty tons. In the case of the Homestead, Iowa, fall (Figure 5), the shower was limited to an area of some five by seven miles, though what was apparently the main portion of the shower continued on its

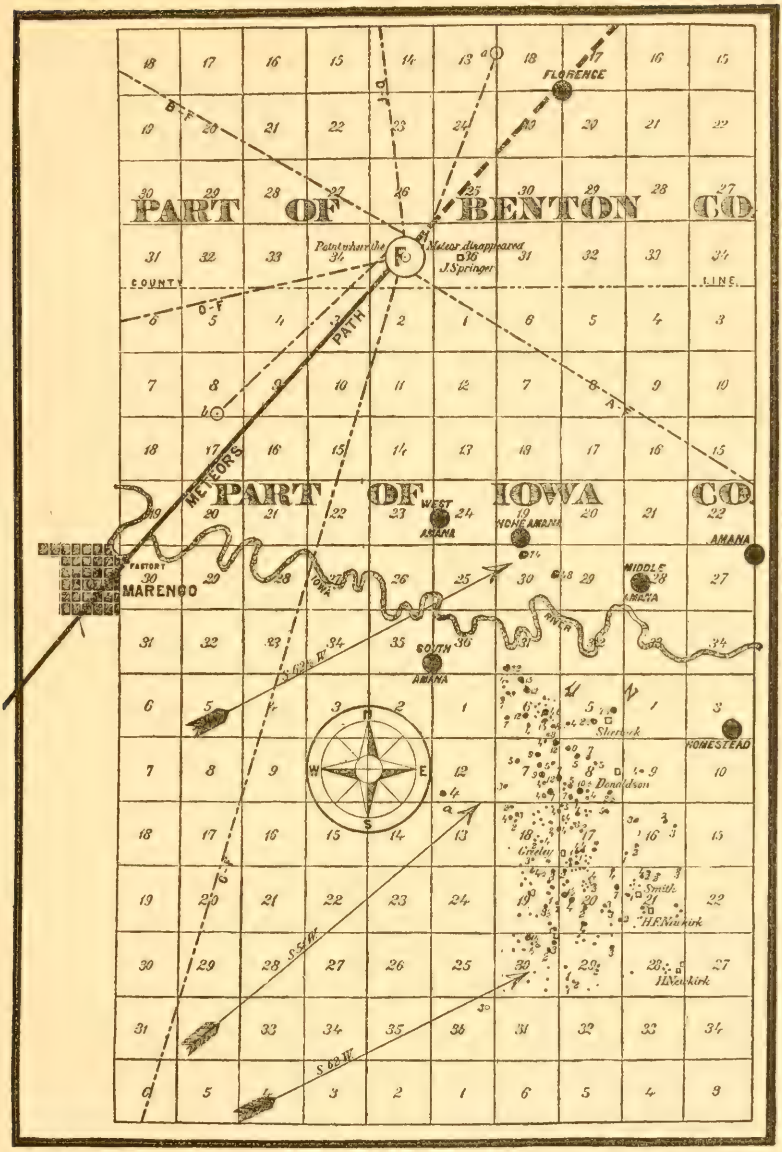


FIG. 5. Map showing areal distribution of stones of the Homestead, Iowa, fall

way and so far as is known did not reach the earth at all. The Guernsey County, Ohio (New Concord), fall comprised over thirty stones weighing altogether some 460 pounds, which were scattered over an elliptical area ten miles long by three miles broad. On the other hand, many falls, as in the case of that of Allegan, Michigan, or Bishopville, South Carolina, are limited to a single stone, or iron, as the case may be.

There is at present no law known which covers the geographical distribution of meteor falls. Indeed, the irregularity of distribution is so great as to render almost hopeless any attempt at a solution. A possible cause which seems applicable to one locality is shown to be utterly inapplicable to any other. Thus the suggestion based on the abundant falls in our southern Appalachians, to the effect that such frequency might be due to the increased attraction of gravity in mountainous regions, is rendered inadequate by the fact that no such increase actually exists, and that, moreover, but two falls have been reported for the entire area of the Swiss Alps; while on the other hand, eighteen have been reported from the flat plains of Kansas with an average elevation of less than 3,000 feet. That the recorded number is due to density of population and hence an apparent increase in the number of observers is negatived by the fact that but one meteorite has as yet been reported throughout the entire Chinese Empire,[1] while India has over 100 to her credit, and Russia sixty-eight. Soil and climate have undoubtedly much to do with the *finding* of the meteorites after they have once fallen and with their preservation, but no single cause that has stood the test of close analysis has as yet been suggested for this inequality. In view of the short life of a meteorite after reaching our soil, and the brief period of falling and observation available for deductive reasoning, it is

[1] Yet Biot, in his *Catalogue général des étoiles filantes*, 1841, records hundreds of such occurrences during the period between the seventh century, B.C. and the seventeenth century, A.D.

perhaps useless to expect a solution of the problem for many years to come.

As bearing upon this, the following tables are of interest:

GEOGRAPHIC DISTRIBUTION OF METEORITES IN NORTH AMERICA UP TO 1925

Alabama	11	Maryland	3	Oregon	3
Alaska	1	Michigan	5	Pennsylvania	5
Arizona	7	Minnesota	2	South Carolina	5
Arkansas	2	Mississippi	3	South Dakota	2
California	7	Missouri	11	Tennessee	18
Colorado	9	Montana	1	Texas	24
Connecticut	1	Nebraska	9	Utah	2
Florida	2	Nevada	1	Virginia	10
Georgia	15	New Jersey	1	West Virginia	2
Idaho	1	New Mexico	10	Wisconsin	6
Indiana	6	New York	6	Wyoming	1
Iowa	4	North Carolina	22		
Kansas	18	North Dakota	3	Canada	11
Kentucky	16	Ohio	6	Mexico	44
Maine	4	Oklahoma	1	Central America	3
Total					324

TABLE SHOWING APPROXIMATE NUMBER, KIND, AND GEOGRAPHIC DISTRIBUTION OF METEORITES UP TO 1925

Country	Irons	Stones	Stony Irons	Totals
North America	209	102	13	324
South America	30	16	6	52
Europe*	29	225	8	262
Africa	25	27	..	52
Australia**	32	17	5	54
India	3	95	2	100
Japan	3	12	..	15
Siberia	10	6	2	18
All Others	7	17	1	25
Totals	348	517	37	902

* Including Great Britain and Ireland.

** Including New Zealand and Tasmania.

Few natural phenomena are more likely to unduly excite the imagination than those attendant upon a fall of meteorites. The suddenness, the unexpected nature of the occurrence, the light and noise, and, perhaps above all, the sensation aroused from the sudden projection of a solid body from seemingly empty space, all have their effect; and it is not surprising that accounts by various individuals are widely variable, dependent upon the flexibility of the imagination, perhaps, more than upon powers of observation. Few persons, however well trained, can look calmly and with judgment upon the phenomenon. Fewer yet can, in the brief space of time, estimate the height of the body when first seen or note such data as may be of service in calculating its rate of progress.

An interesting feature of the phenomenon is the lack of ability on the part of the observer to exactly locate the place of fall, unless, indeed, he happens actually to see it strike the ground. This is due to several causes and, in part at least, to the varying angles at which the stones sometimes enter our atmosphere, which may permit a continuation of flight for long distances beyond the point at which they seemingly must strike the earth, and in part to the fact that one is unable to correctly estimate the distance of bodies falling from a height which may be much greater than supposed. The late H. A. Ward once told the writer of his experience in such matters. He was sitting in front of a house occupying a somewhat elevated position with reference to the rest of the town. Suddenly a meteorite appeared descending from the sky, and fell, he was sure, within a certain square on the lower level. He at once proceeded to the spot, only to find that he was mistaken and that it had fallen "a few blocks away." At this second point the same experience was repeated and the stone finally located some twenty miles beyond the point where he was "certain" he had seen it strike.

An even better illustration was offered some years ago by a meteor passing over the city of Washington. It was first reported to the writer by a man fishing in the Potomac some eighty miles south of the city. He saw it strike—was certain of it—within a half a mile of where he was standing; offered to go and get it if properly reimbursed. As, however, a meteor had passed over Washington, traveling in the same direction, on the same day at the same hour, the offer was not accepted. The meteor was also "seen" by various individuals to strike on the roof of an apartment house within the city limits, and by others to fall in Chevy Chase, a few miles to the north. In both cases supposed fragments were collected and forwarded for examination. Not one proved to be meteoric. By writing to postmasters along the line of direction in which the meteor appeared to be traveling, it was actually traced from where it was first "seen to fall" for nearly 300 miles into northeastern Pennsylvania, and it was still going! If it fell at all, no trace of it has been discovered.

Almost without number are the instances in which stones have been picked up which "were seen to fall" but which prove to be strictly of terrestrial origin. There comes a sudden flash and report, the observer goes quickly to the spot where the meteorite was thought to strike, and there finds an object which had not previously attracted his attention, although he may have been over the ground many times. This is at once assumed to be the meteorite, and in perfect good faith he writes to some museum, announcing his discovery and willingness to dispose of the newly discovered meteorite. There is probably not a museum of importance in the world that does not annually receive one or many such finds which, on examination prove to be glacial bowlders, residual masses of iron ore, or any of the less common materials that strew the ground of the particular locality. The writer has repeatedly had material sent him which was even "warm when picked up" and found it to be but a bowlder which had lain upon the spot where it was found during all the years that have elapsed since the final retiring of the ice sheet of the glacial period. Few lines of investigation are better calculated to unfit one for jury duty where are involved grave questions in human testimony concerning sudden phenomena than that relating to the study of meteorites.

Under particularly favorable conditions, as where a falling meteor has been noted from different standpoints by several observers, it has been possible through plotting the recorded observations of azimuth and altitude to locate the point of probable contact with sufficient accuracy to warrant a systematic search. It was through such means that portions of the Bath Furnace and Cumberland Falls stones were found.[2] Doubtless the meteor which passed over Washington in January, 1921, already referred to, might in like manner have been found had sufficient time been devoted to it, and in cases where there has been a shower, as at Holbrook, Arizona, and elsewhere, there is always the chance of finding more.

Of all instruments and instrumentalities for finding meteorites, where not actually seen to fall, the humble plow and its less humble holder have proved most fruitful. "Found while plowing" has become almost stereotyped through its abundant repetition. The Admire and Anthony finds in Kansas, the Burlington, New York, and Carlton, Texas, finds may be mentioned among the many that have thus been brought to light. The reason for this is almost self-evident, particularly if the region be one free from drift or one of sedimentary rocks only, like our lower Mississippi Valley. The plow strikes an obstruction, which, on examination, is found to be of metal, or, if of stone, unlike anything in the neighborhood; curiosity is excited and it is taken home to hold down a well or barrel cover, where its nature is ultimately dis-

[2] A. M. Miller, *Sci. Monthly*, Nov., 1923.

covered by a chance traveler; or the finder may himself have been of a sufficiently inquisitive mind to send it away (to the Smithsonian or elsewhere) to have its nature determined. The pallasite of Brenham County, Kansas, offers a good illustration of this chance finding. The region is that of a prairie, with deep, stoneless soil. Hence great surprise and curiosity was manifest when the mowing machines and plows struck projecting masses of heavy, dark-colored rocks. Over twenty were found in different parts of the area, weighing altogether about a ton. The larger were collected and utilized in holding down haystacks and barrel covers until their nature and value were discovered.

That so many examples have been found in the flat and treeless prairie lands is thus readily explained. That so many are found in desert regions is due to a lack of vegetable covering to obscure them, and to their long preservation in a dry soil and atmosphere. There is on record the case of a young man in Texas who, on finding a rounded, dark-colored stone unlike others in the neighborhood, sent it away for identification, and on learning its true nature, made a systematic search and found some score of additional individuals which yielded him a very satisfactory pecuniary reward when they were distributed among collectors. These were, however, all products of the same fall.[3] The Canyon Diablo find was of like nature and will doubtless yield still other smaller individuals to chance finders.

Reference is made on page 47 to mistakes that have occurred in the identification of supposed meteoric material, and the question naturally arises: By what means is it possible for one to identify a meteorite even with a reasonable degree of safety? The best and most general rule is an empirical one. Experience in handling and

[3] In this connection it may be well to state that in the few cases in which the ownership of a newly-found meteorite came to the courts for decision, the verdict has been invariably in favor of the owner of the land on which the object was found.

studying will afford safer criteria than any number of tests made by one inexperienced. Nevertheless, there are characters easily recognized that will serve to guide one along the road of probabilities. If the object found is metallic and malleable, *i.e.*, impressible without shattering under the hammer, and found elsewhere than near iron-smelting works, the chances are sufficiently in favor of its meteoric nature to warrant its being examined with care. If, when submitted to a chemist, it reacts not alone for iron but for nickel as well, this is nearly conclusive and it should be judged further by an expert, with particular reference to its crystalline structure. If the object is a stone, or largely of stony matter, it will invariably show, if freshly fallen, a thin, dark crust, sometimes black and smooth, sometimes slightly shagreened. This crust will extend entirely over the surface except where broken in the fall, and the stone beneath shows no signs of fusion or of heat in any degree. Further than this, a freshly broken surface will nearly always reveal little projecting points of metallic iron which can be felt if too small for easy recognition otherwise. With the exception of a few rare cases of basaltic rocks, instances of this kind are unknown among terrestrial equivalents. Beyond this the inexperienced can rarely go, though a chemist may be of some assistance in determining the presence or absence of nickel. Either stone or iron will invariably, if fresh, show the effects of its flight through the air—not by the crust alone, as already mentioned, but by pittings, thumb markings, or piezoglyphs, formed as elsewhere described. If the object "picked up with stones to make a wall" (to quote a line from the poet Frost) fulfills all these criteria, the chances are greatly in favor of its actual meteoric nature.

But, as already stated, meteorites, owing to their peculiar mineral composition, are of an extremely perishable nature and only when almost immediately gathered will they be found fresh and unaltered. The first change manifest is that of oxidation of the iron chloride, lawrencite, which freckles a broken surface with rust-colored spots, and which, if abundant, gradually stains it throughout and perhaps produces disintegration. The same constituent in an iron causes it to sweat with drops of rusty moisture and to ultimately exfoliate and fall to pieces. In some cases, as in that of the Admire, Kansas, stony iron, the oxidation proceeded in such a manner as to actually hermetically seal and protect the inner portion so that when found it resembled nothing more than an irregular lump of brown iron ore. When broken, the unoxidized interior showed its true nature; but unfortunately decomposition at once set in again, and in spite of utmost care, this interesting meteorite is represented in collections today by crumbling fragments which can be prevented wholly from destruction only by immersion in a petroleum distillate or some similar fluid. The trouble is, of course, not due to the chloride alone, since metallic iron and the iron sulphide, troilite, are themselves vulnerable to the attacks of a moist atmosphere, and given time enough, the results will be the same.

The so-called "shale balls" once so common in the Canyon Diablo region, are but oxidized masses which in some cases, when broken, still show a residual nucleus of metal like an oyster in its shell. But for the dryness of the climate, these too would doubtless have long since become unrecognizable as meteorites.[4]

On account of the halo which naturally surrounds an object of such mysterious origin, meteorites have been eagerly sought by collectors—so eagerly, indeed, that stones and irons have been divided and subdivided to a degree bordering upon the absurd and far removed from scientific. The desire on the part of collectors to secure representatives of the fullest possible number of falls has not only led them to bid prices foolishly high but

[4] The writer brought several shale balls with such nuclei to Washington only to have them go to pieces notwithstanding all the care that could be exercised.

has caused a stone—if of only moderate size—to be broken into bits and so widely distributed that it has been impossible in later years to secure enough for study. Catalogues of collections have been printed in which certain rare falls were represented by fragments weighing but 0.1 or 0.2 of a gram, or a little larger than the point of an ordinary lead pencil. Prices have soared accordingly and instances may be cited in which five to ten dollars a gram has been paid. The small meteorite which fell in Kilbourn, Wisconsin (Plate 40), in 1911, and passed through a board in the roof of a barn, sold as high as seven dollars a gram, largely on this account, as it was a stone of a common chondritic type. Obviously a meteorite has no *actual* value and these prices are not only wholly artificial and unscientific, but silly. It should be added that this condition is due largely to the mere collector rather than to the serious student. Ambitious heads of departments in our public museums are, however, by no means blameless.[5]

In the now commonly adopted system, valuation of a meteorite is based upon the following eight factors, of which the first three are considered of primary importance:[6]

[5] The meteorite of Juvinas, France, of which there was originally upwards of fifty kilograms, has been broken up and distributed among sixty-two collections, of which three report one gram each and nineteen others less than ten grams each; that of Stannern, Austria, of which there was upwards of thirty-eight kilograms, has likewise been distributed among ninety-six collections of which the Vienna museum has about one-sixth, four others upwards of a kilogram, and the remainder, scattered amounts of from one to 850 grams. Of the Bialystok howardite, of which there was originally upwards of two kilograms, but 627 grams are now known, distributed among eighteen collections, of which the largest sample is but 120 grams; no analysis has been made through want of material. Of the Frankfort, Alabama, stone, weighing originally but 615 grams, the location of 535 grams is accounted for, distributed among eighteen collections, the largest sample being but 255 grams and four catalogued as mere "splinters." The climax is reached, however, in the case of the stone of Nobleboro, Maine, of which there was originally from four to six pounds; but seventy-eight grams are now accounted for, distributed among eleven collections, seven of which record only "splinters."

[6] See H. A. Ward, Values of Meteorites, *The Mineral Collector*, Sept., 1904; and W. M. Foote, Factors in the Exchange Values of Meteorites, *Proc. Amer. Philos. Soc.*, Vol. 52, 1913.

1. Present known weight of the fall.
2. Petrographic composition.
3. Number of owners of pieces.
4. Material which may still come to light.
5. Difficulty of obtaining from present holders.
6. State of preservation.
7. Historical interest.
8. Was it seen to fall?

Obviously such a ratio is based almost wholly upon the demands of the mere collector—he who wants a thing chiefly because it is rare. To the real student only the second, sixth, and eighth items are of more than secondary interest, and several, such as the third and fifth, of none whatever. Those upon which a real scientific value may be placed are: petrographic characters, details of fall, and state of preservation.

Nearly all large public museums now have meteorite collections, the largest being in Vienna, Paris, and London abroad, and Chicago, New York, Washington, and Harvard and Yale universities in America. In one or two instances their numbers in representative fragments and more or less complete individuals run as high as 500 to 700 distinct falls and finds.

CHAPTER IV

THE NUMBER, SIZE, AND FORM OF METEORITES

It is estimated by astronomers, as elsewhere stated, that 400,000,000 meteors penetrate our atmosphere daily, and of these 20,000,000 are of sufficient size to form shooting stars. It must be remembered, however, that a particle weighing not more than a gram, and of which, therefore, it would require between 400 and 500 to make a pound, is of sufficient size to be visible after sundown. Of these 20,000,000, comparatively few are found even if they survive to reach the earth, as may readily be imagined, being too small for recognition.[1] Moreover, but one-fourth of the earth's surface is land and but a comparatively small portion of this so occupied by intelligent human beings as to make finds probable even were the falls noticed, while falls during daylight of any but large stones would be likely to be overlooked or disregarded everywhere. It will in this connection be well to call attention to the enormous discrepancy between the *apparent* and *actual* sizes of these falling bodies. How great this is may be judged from the fact that very moderate-sized stones have been reported in sizes up to that of the full moon when seen at distances of twenty to one hundred miles. The Hraschina fall, which yielded but two irons weighing sixteen and seventy-one pounds, was estimated to have an apparent diameter of 3,000 feet.

[1] The number that fell during the five or six hours of the shower of Nov. 12, 1833, was estimated by an observer in Boston at 250,000. There was no sound and, so far as known, not one came to earth.

According to G. von Niessel,[2] Herschel concluded, from a comparison of the light power of a shooting star at a given distance with that of a given mass of gas, that a meteor of first magnitude weighs on the average very few grams, and that the smaller meteors weigh only a fraction of a gram. By similar comparisons with the Drummond light, V. F. Sands, with reference to the Leonids of 1867, found the following estimates:

Apparent brightness that of	Mass or weight of corresponding meteor
Jupiter	0.67 grams
Sirius	0.45 "
First magnitude star	0.06 "
Second magnitude star	0.02 "
Third magnitude star	0.01 "
Fourth magnitude star	0.006 "
Fifth magnitude star	0.004 "

F. Berwerth estimated that but about 900 recognizable meteorites fall annually upon the earth,[3] and of this number, three-fourths would be lost in the oceans, leaving but 225 for the land. In addition it must be remembered that the mineral nature of a meteorite is such that few of them survive for any prolonged period after falling, except in very dry regions. Even of these but a small fraction (not more than three or four annually) find their way into collections. Ward, in 1904, listed 815 known individual meteorites, of which 680 were represented in the various collections. Prior, in his catalogue of 1923, listed 849. A still more recent (1925) count places the number at 902.

The smallest known meteorite comprising an entire fall is that of Mühlau, Austria. This is now in the Vienna Museum. It weighs five grams, and being a stone, is about as large as a filbert, or the end of one's finger. The

[2] Determination of Meteor Orbits in the Solar System, *Smithsonian Misc. Coll.*, Vol. 56, No. 16, 1917.

[3] Schreibers made an earlier estimate of 700.

largest known meteorite is the metal monster brought by Peary from Cape York, Greenland. This weighs, according to the authorities of the American Museum of Natural History, 37½ tons, or 34,014 kilograms.[4] Following in the order of decreasing sizes are the Bacubirito iron of Mexico (Plate 15), estimated to weigh 27,500 kilograms; the Willamette iron of Oregon, weighing 14,140 kilograms; and the Bendego iron of Brazil, weighing 5,370 kilograms. All of these, it will be noted, are of metal, the largest single stone thus far found being that of Estacado, Texas, which was reported to have weighed 290 kilograms. Unfortunately this has been cut up and distributed. The largest individual of the Knyahinya fall weighed 250 kilograms. The next largest is that of Selma, Alabama, which weighs 138.6 kilograms. The comparatively small size of the stony forms must be ascribed to their brittle nature which causes them to break up in the latter portion of their flight. For purposes of comparison consideration should be given to the total weight of all the individuals of a fall, so far as obtainable. That of the Knyahinya shower was nearly 500 kilograms; of the Estherville, 337 kilograms; of the Mocs, perhaps 300 kilograms; of the Long Island, Kansas, 1,976 kilograms; and, according to Foote's estimate, for the 14,000 individuals of the Holbrook shower, 218 kilograms.

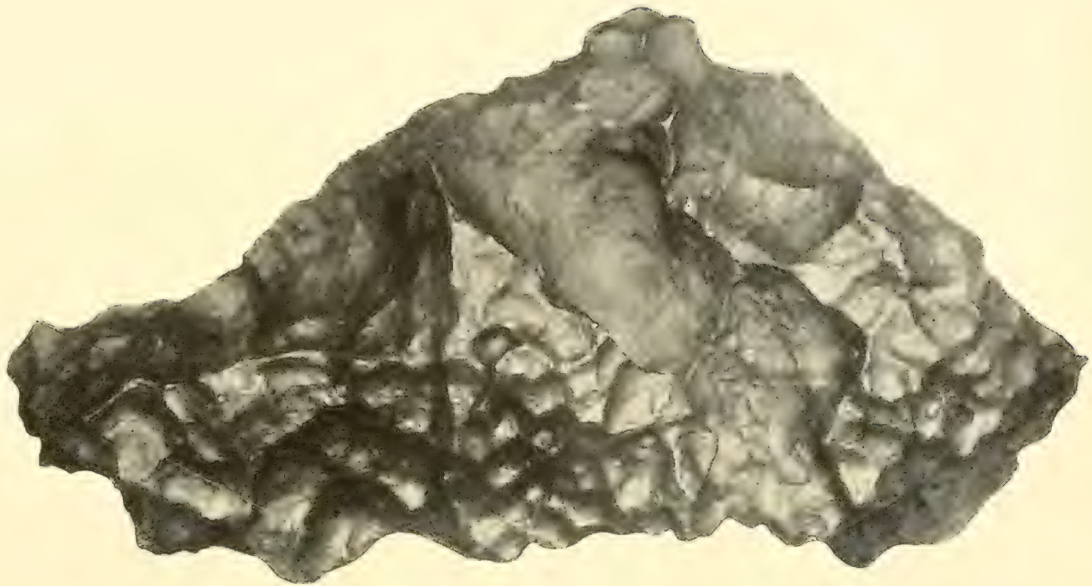
The total weight of all known falls and finds of meteoric material to be found in the various collections was estimated by Wülfing in 1897 to be but 32,500 kilograms, or a little short of 40 metric tons. This, of course, was not the total weight of the falls, nor did it include the giant masses since reported from Cape York, Bacubirito, Willamette, and Quinn Canyon, nor the estimated total of the Canyon Diablo and various Mexican falls. A recent estimate of weights of all known falls and finds, up to 1927, including the large masses mentioned and those since Wülfing's time, gives a total of 219,151 kilo-

[4] A kilogram equals 2.205 pounds avoirdupois.

PLATE 15

The Bacubirito, Sinaloa, Mexico, Meteoric Iron lying as found but partially uncovered

PLATE 16



Iron Meteorite: Owens Valley, Inyo Co., California. Found by sheepherder in 1913, and presented to the National Museum by Mr. Lincoln Ellsworth. Length 65 centimeters; weight 193.17 kilograms (425 lbs.). The iron shows to excellent advantage the so-called "piezoglyphs," or "thumb markings" grams, or 483,008 pounds. The most that can be said concerning such an estimate is that it is underweight to an indefinite extent.[5]

It was long since conceded that the original form of a meteorite was that of a fragment, and that in the majority of cases this fragmentation had been renewed after the body entered the earth's atmosphere. The processes by which this last phase was brought about have been sufficiently dwelt upon elsewhere. The various forms presented by the fallen body are due to the original form of the fragment and the burning away of the surface to an extent dependent upon the speed of the meteorite, its mineralogical nature, and state of aggregation. Friable stones may continue to break throughout their course, giving rise to fragments quickly rounded by burning and resulting in irregularly rounded, pebblelike forms coated with the black crust. Firmer, more resistant stones may give rise to sharply angular forms, only the edges of which become rounded and the surface smoothed. When of sufficient size or of a form to hold their position for any length of time, such stones become smoothed on the face that is foremost—the nose, or the "*brustseite*" as the Germans call it—and not infrequently show radial lines or furrows (Plate 34) extending back toward the rear, caused by the rush of the air. So constant are these that it is possible for one conversant with the subject to tell which face of any meteorite was foremost in its flight. The numerous depressions, thumb markings, or *piezoglyphs* such as are shown by the Owens Valley iron are due in part to the unequal resistance of various portions of an unhomogeneous character. (Plate 16.) These markings at times so closely simulate those made by a human hand as,

[5] It will be recalled (see page 4) that, on the basis of an annual deposit of 93,000 tons of meteoric matter, it was estimated that it would require 350,000,000 years to form an accumulation one inch in thickness over the entire earth. An incidental effect of this increase in weight would be a slowing up of the earth's speed of rotation amounting to .001 second in a million years. An equally interesting estimate is that the passage of these meteors through our atmosphere generates yearly as much heat as that received from the sun in 0.01 of a second.

in one instance at least,[6] to have given rise to the thought that the stone was soft and plastic when found and received the impress of the fingers and palm when pulled out of the earth in which it had buried itself! Nodules of troilite, or troilite and carbon, such as are so conspicuous a feature of the Canyon Diablo iron, quickly yield to the rush of air, burn away and leave pits or holes perhaps extending quite through the mass.[7]

That flattened irons like those of Oakley, Idaho; N'Gourema, Africa; Cabin Creek, Arkansas; and Algoma, Wisconsin, should come broadside through the atmosphere instead of edgewise may at first seem strange but that they do so is proven beyond controversy by their surface markings; moreover, that the position is normal has been mathematically demonstrated.

The rapidity with which the surface of a stone becomes fused and its irregularities smoothed in the short period of flight is wonderful. Instances are by no means rare in which individual stones belonging to one and the same fall have acquired crusts of the first, second, and even third order, due to successive breakings and the fusion of each successively exposed surface. Naturally, owing to lessening speed, each new crust is thinner than the older, and may be but a mere film scarcely distinguishable, affecting the more prominent points on the rough surface.

It is doubtless due to their refractory nature that iron meteorites come to earth in larger sizes than stones, and this notwithstanding the more rapid combustion they may undergo owing to the increased rapidity of flight—if we accept this as demonstrated. However this may be, it is well known, as elsewhere stated, that individual irons vastly outweigh the stones. The largest amount of stony material constituting a single fall is that of Knyahinya

[6] The Haraiya meteorite. *Rec. Geol. Surv. India*, Vol. 35, 1907, p. 91.

[7] See also Berwerth's *Etwas über die Gestalt und Oberfläche der Meteoriten, Festschrift des Naturwissenschaftlichen Vereins an der Universitat Wien*, 1907.

noted above; the largest *complete* individual reported is that of Estacado which weighed 290 kilograms (638 pounds) while the single mass of metal brought from Cape York by Peary weighed 34,014 kilograms (75,000 pounds). On the supposition that these larger masses suffered a loss equal to that estimated by Wimperis, the originals were surely of considerable size, though just what limit is to be placed on the word "considerable" is problematical.

Showers of iron meteorites, such as have been described in the case of stones, are quite unknown. The apparent anomaly in the Canyon Diablo occurrence is in all probability due to the fact that the irons fell, not as single individuals, but as loosely aggregated masses composed perhaps of troilite or other easily decomposable material enclosing the metal which has since been liberated through decomposition. The form of the smaller irons of this fall, with their sharp points and edges, is conclusive evidence of their not falling singly.

The coarse crystallization of many meteoric irons, particularly the octahedral varieties, has been considered by some indicative of very slow cooling, and this in itself would indicate masses of some magnitude. Perhaps one might gain a better perspective through a consideration of the conditions under which such a mass could have originated. Owing to the abundant illustrations that have come to earth of meteorites composed mainly of silicates with merely a trace of metal, through all intermediate forms to those almost wholly metallic, it is possible to conceive of the latter as simply metallic segregations out of stony masses of much greater dimensions, in which case it would not be difficult to imagine the mammoth forms mentioned as from bodies of planetary sizes. This is, of course, purely speculative.

One of the most suggestive meteoric masses that have recently come up for consideration in following this line of thought is that of Cumberland Falls, Kentucky, which fell April 9, 1919. This meteorite, it will be remembered, is a siliceous breccia,[8] composed of fragments of two quite different types, the one a coarse, nearly white pyroxenite;[9] and the other a compact, nearly black chondritic[10] stone. (See Plate 17.) That the original mass from which they were derived was broken either by impact, explosion, or crushing into fragments which were then intermingled and recompacted, is self-evident. Judging by comparison with terrestrial rocks, one would consider the stone a volcanic breccia, *i.e.*, a recompacted mass of fragments produced through explosive volcanic action. Whether both kinds of stone were from the same or different volcanoes is immaterial. They were intermingled and then subjected to sufficient compressive force to bring about the present degree of firmness. That this compression could be brought about by weight of overlying matter is doubtful. In all probability it was the result of such crustal movements as are operative in producing sharp folding. The degree of compactness, it is to be observed, is considerable—enough to permit the production of a smooth surface and a polish. It is well to note incidentally that the absence of secondary minerals, unless the metal be so considered, is indicative of an absence of moisture of any kind. Particular attention is called to the fact that the present structural features can seemingly be accounted for only on the basis of a parent mass of no inconsiderable size—one in which crustal stresses, as in our own planet, would result in compression and consequent reconsolidation of fragmental detritus as suggested in the original descriptive paper.[11] There is seemingly no escape from the conclusion that the source of this meteorite was a body of planetary dimensions, though

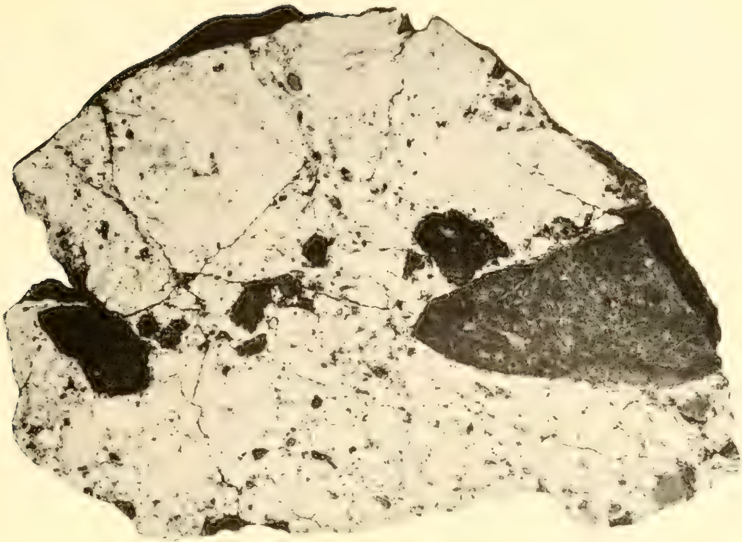
[8] A "breccia" is a rock made up of recompacted fragments.

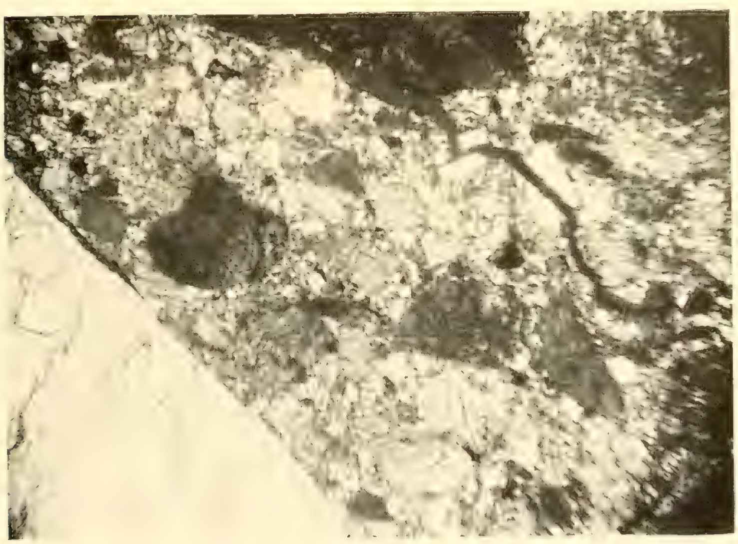
[9] A "pyroxenite" is an igneous crystalline rock composed largely of the mineral pyroxene.

[10] Chondritic structure, for explanation see page 75.

[11] *Proc. U. S. Nation. Mus.*, Vol. 57, 1920, pp. 97–105.

PLATE 17





2

(1) A polished slice of the Cumberland Falls, Kentucky, meteoric stone about natural size and (2) a portion of the same magnified

whether or no a portion of Olbers's lost planet must be left for astronomers.

Elsewhere mention is made of the possibility that distant nebulous celestial masses may be of meteoric material. That there exists in the far reaches of space a considerable and incalculable quantity of meteoric or cosmic material in the form of dust is unquestionable.[12] That a portion of it comes to earth is beyond reasonable doubt and obviously there is no occasion for placing a downward limit on the size of meteoric particles. Moreover it is obvious that the burning meteorites in the upper air leave a residue which must sometime find its way to earth in dustlike form. "Cosmic dust" has come to be considered an actuality, though a large part of the material examined and described under this name is of terrestrial origin. Here mention will be made only of dusts found under conditions such as to make their sources problematical, and the determination of which is dependent upon the kinds of material of which they are composed rather than upon their mode of occurrence. The universally prevalent nature of dusts of some kind, it may be stated, is little realized by the casual observer, who can, however, be quickly brought to a condition of realization by so commonplace a method as that of viewing a sunbeam coming from a narrow opening into a darkened room.

Naturally there are great, if not insuperable, difficulties in determining from mode of occurrence alone what might have been the possible source of a deposit. Not merely do volcanoes occasionally eject dust particles so high in the air that they may be even years in settling to earth, as was the case with Krakatoa in 1883, but the winds under favorable conditions will transport fine material, such as the ejectamenta from blast furnaces in manufacturing districts, to such heights and such distances

[12] "L'espace autour du soliel est, on le sait, rempli de matère cosmique, et de matière cosmique, et de matière cosmique de tous degrés de tenuité et de grosseur." Moigno's *Cosmos.*

that the original sources become problematical. The best points for observation and collection of materials, and those where there is least danger of contamination, would appear to be high mountain peaks and other regions covered over many miles of area with perpetual ice and snow.

But few instances need be mentioned. Von Lasaulx, who examined a large number of samples of dust from various sources, found them to consist of well-recognized terrestrial particles, sometimes volcanic and sometimes wind-swept products of gneissic and granitic rocks. Dust obtained from the melting of pure snow yielded likewise only terrestrial material. On the other hand, dust collected from the Chilean Cordilleras at heights of from 11,000 to 16,000 feet and examined by K. Stolp and A. E. Nordenskiöld, were by both, on account of the mineral composition, relegated to a cosmic—"*welten-raum*"—source. O. Silvestri arrived at a like conclusion from an examination of dust which fell in Catania.

In 1880, a committee from the British Association reported an examination of dusts from the open Atlantic and the Red Sea. These had been commonly regarded as meteoric. It was conclusively shown that they were terrestrial and composed of the fine sands driven from northern Africa. Three samples of dust collected from snow and ice in the Himalayas and remote from manufacturing establishments or habitations of any kind contained spherical particles of magnetic iron and minute shreds of native metal. These were thought to be of meteoric origin. A. E. Nordenskiöld, in his Greenland expedition of 1870, collected from holes in the ice a fine gray powder which he called *cryoconite*, which contained particles of metallic iron and gave reactions for cobalt and copper but consisted principally of white, angular particles of feldspar and augite. Later, in 1873, he found minute rounded grains of metallic iron in hailstones that fell at Stockholm, Sweden. In both cases the metallic particles were considered meteoric.

The historically dark days of 1090, 1203, 1547, and 1706, in Europe, were thought by Chladni and others to be caused by clouds of meteoric dust cutting off the sun's rays, though this may now be considered doubtful. Dust which obscured the sun for two days of 1840, in Russia, was found by Ehrenberg to be made up of diatoms and other organic and inorganic matter from terrestrial sources.

Perhaps in this connection one might refer to the meteoric material dredged during the *Challenger* expedition from almost abyssal depths of the South Pacific Ocean, far removed from possible land contamination. This consisted of spherical, chondrule-like particles of metal and pyroxenes, identical with the chondritic forms of meteorites and unlike anything of known terrestrial origin. While it is true that a large part of this might have arisen from the breaking up (explosion) of meteorites as they approach the earth and are in our atmosphere, it is a fair assumption that a portion may have been derived from the remote original source of the meteorite itself.

On the whole it is fair to assume that, regardless of all discrepancies in reports, there is at all times and everywhere an imperceptible rain upon the earth of meteoric dust, though so contaminated with that of terrestrial origin as to make its detection difficult.

CHAPTER V

THE COMPOSITION AND STRUCTURE OF METEORITES

There are only two avenues to our knowledge of the universe outside of us, one being light, by the agency of which the motions of the heavenly bodies are revealed to us, while the other consists in the masses of matter that come to our earth from that outer universe.[1]

REALIZING that our earth is but one of a myriad of bodies flying through space, one's interest is naturally aroused by the consideration of how it agrees both in composition and structure with its distant fellows. Such a determination can be made only (1) through the agency of light, and (2) through the aid of chemistry and mineralogy. With the aid of the spectroscope it was long ago shown that the sun and more distant star bodies were of the same elemental composition as the earth. It failed, however, to show how these elements were combined and their relative abundance. These questions can be solved only by a study of the solid bodies that come to us from space—in other words, from meteorites. It is for this reason that the study of meteorites is so interesting and important. To be able to show that there is throughout all known space a practical sameness of material, solid, liquid, or gaseous, is indeed a wonderful accomplishment. Equally wonderful is it to show that the form of combination of these elements is to a very considerable extent the same as on our earth, and when different, due not to a variation in chemical affinities but to surrounding conditions, and particularly diminishing quantities of certain elements common to our earth and its atmosphere.

[1] Humboldt as quoted by Maskelyne.

Through the aid of chemical analyses and the study under the microscope of meteorites that have been cut into small slices so thin as to be translucent if not transparent, we have been able to determine the form of combination of the various elements, the kinds of minerals resulting, and the various processes of rock consolidation and crystallization, just as in the case of their terrestrial counterparts. What is the result?

We have learned that out of the eighty-four known elements but twenty-eight occur in meteorites in sufficient abundance to need mention here. The most abundant of these, named in alphabetical order, are aluminum, calcium, carbon, iron, magnesium, nickel, oxygen, phosphorus, silicon, and sulphur. In smaller quantities, sometimes so slight as to require careful work for their detection, are chlorine, chromium, cobalt, copper, hydrogen, iridium, lithium, manganese, nitrogen, palladium, platinum, potassium, ruthenium, sodium, titanium, vanadium, and probably also argon and helium. The presence of antimony, arsenic, gold, lead, strontium, tin, and zinc have from time to time been reported, but recent investigations have thrown doubt upon the accuracy of the determinations.[2]

Under the conditions prevailing upon the surface of the earth and to an unknown extent elsewhere, most elements tend to combine, an element like carbon tending, for example, to combine with oxygen and calcium to form the carbonate of calcium known by the mineralogical name of calcite. It sometimes happens that an element has a very weak combining power—is neutral—and makes very few combinations, as is the case with the element nitrogen. Others which would combine are prevented by the absence, or insufficient quantity, of the elements for which they might have an affinity. Oxygen for in-

[2] See G. P. Merrill, *Mem. Nation. Acad. Sci.*, Vol. 14. The results were obtained through *chemical* analyses. It is probable that by means of the spectroscope other constituents in extremely minute proportions could be found. See Hartley and Ramage in *Sci. Proc. Royal Dublin Soc.*, Vol. 8, Part 6, No. 68, 1898.

stance has a strong affinity for iron. When, as in meteorites, we find certain elements, as iron, free (*i.e.*, uncombined), we feel safe in assuming that that particular meteorite was formed in a distant region of space where there was a deficiency of oxygen as compared with our atmosphere, which is certainly an interesting item in what may be called the life history of a meteorite. That the conditions were not wholly dissimilar is, however, apparently shown by the presence in meteorites of certain minerals characteristic of terrestrial rocks as well.

Fig. 6. Diamond crystal out of Canyon Diablo meteorite. Actual size about 1/100 of an inch. (After O. W. Huntington)

The following list comprises the meteoric minerals found in both meteoric and terrestrial rocks: olivine; the pyroxenes; the plagioclase feldspars; apatite; magnetite; chromite; quartz; pyrrhotite; free carbon; and rarely, the diamond in microscopic quantities. These are all found in terrestrial igneous rocks of the nature of basalt and peridotite. The meteoric minerals found rarely, if ever, in terrestrial rocks are the various alloys of iron and nickel known as kamacite, taenite, and plessite; the nickel-iron phosphide, schreibersite; the iron monosulphide, troilite; the iron and chromium sulphide, daubréelite; the iron protochloride, lawrencite; the calcium and titanium or zirconium oxysulphide, osbornite; the calcium sodium phosphate, merrillite; the iron and nickel carbide, cohenite; an isotropic feldspathic mineral called maskelynite; and a form of silica called asmanite, which may after all be the same as the terrestrial mineral, tridymite.

With this much in the way of elemental and mineral composition it will now be well to consider the total average composition of meteorites of various kinds and to compare them with the rocks composing the available portion of the earth's crust. In doing this however, we have first to remark that the meteorites are roughly classified into three main divisions: (1) those that are practically all metal, known as iron meteorites, or meteoric irons; (2) those consisting of a spongelike mass of metal the interstices of which are occupied by silicate minerals—mainly olivine—known as stony irons or pallasites; and (3) those which are composed almost wholly of stony-silicate minerals, known as meteoric stones, or aerolites. The known relative proportions of these have been given as below:

Total weight of all known meteoric irons	195,643,183 grams
Total weight of all known stony irons	13,884,118 grams
Total weight of all known meteoric stones	9,623,664 grams
Total	219,150,965 grams (483,008 pounds)

Average Chemical Composition of Meteoric Irons

Iron (Fe)	90.63%
Nickel (Ni)	8.51
Cobalt (Co)	0.59
Phosphorus (P)	0.17
Sulphur (S)	0.04
Copper (Cu)	0.02
Chromium (Cr)	0.01
Carbon (C)	0.03
Total	100.00%

Average Composition of Stony-Iron Meteorites (Pallasites)

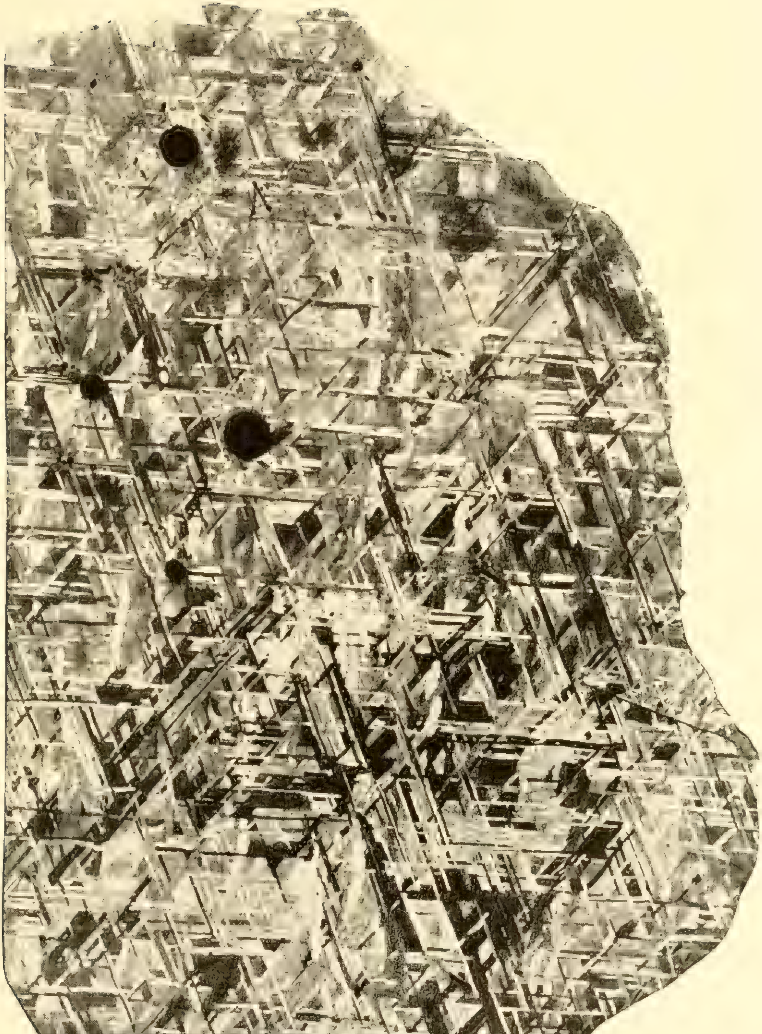
Silica (SiO_2)	20.20%
Ferrous Oxide (FeO)	7.46
Magnesia (MgO)	23.55
Iron (Fe)	43.56
Nickel (Ni)	4.94
Cobalt (Co)	0.29
Total	100.00%

Average Composition of (I) Stony Meteorites, (II) Terrestrial Peridotites, (III) Rocks of the Earth's Crust

Constituent	I	II	III
Silica (SiO_2)	38.68	37.78	59.93
Titanic oxide (TiO_2)	.18	0.58	.74
Tin oxide (SnO_2)	None	....	....
Zirconium oxide (ZrO_2)	None	....	.03
Alumina (Al_2O_3)	2.88	3.11	14.97
Ferric oxide (Fe_2O_3)	....	2.41	2.58
Chromic oxide (Cr_2O_3)	.47	0.19	.05
Vanadium oxide (V_2O_3)	Trace	....	.02
Metallic iron (Fe)	11.98	....	....
Metallic nickel (Ni)	1.15	....	....
Metallic cobalt (Co)	.07	....	....
Ferrous oxide (FeO)	14.58	18.36	3.42
Nickel oxide (NiO)	.48	0.18	.03
Cobalt oxide (CoO)	.06	....	....
Lime (CaO)	2.42	3.06	4.78
Barium oxide (BaO)	None	....	.11
Magnesia (MgO)	22.67	28.38	3.85
Manganous oxide (MnO)	.29	0.31	.10
Strontium oxide (SrO)	None	....	.04
Soda (Na_2O)	.87	0.68	3.40
Potash (K_2O)	.21	0.32	2.99
Lithia (Li_2O)	Trace	....	.01
Water (H_2O)	.75	3.79	1.94
Phosphoric acid (P_2O_5)	.26	0.10	.26
Sulphur (S)	1.80	....	.11
Copper (Cu)	.014	....	....
Carbon (C)	.15	....	....
Chlorine (Cl)	.08	....	.06
Fluorine (F)	None	....	.10
Carbonic acid (CO_2)	(?)	0.75	.48
	100.044	100.00	100.00

These figures are of interest when we consider that the peridotites, which of all terrestrial rocks most nearly compare with meteorites, are of an igneous nature and of comparative insignificance as components of the earth's crust. They occur only as *intrusives*, that is, they have

PLATE 18



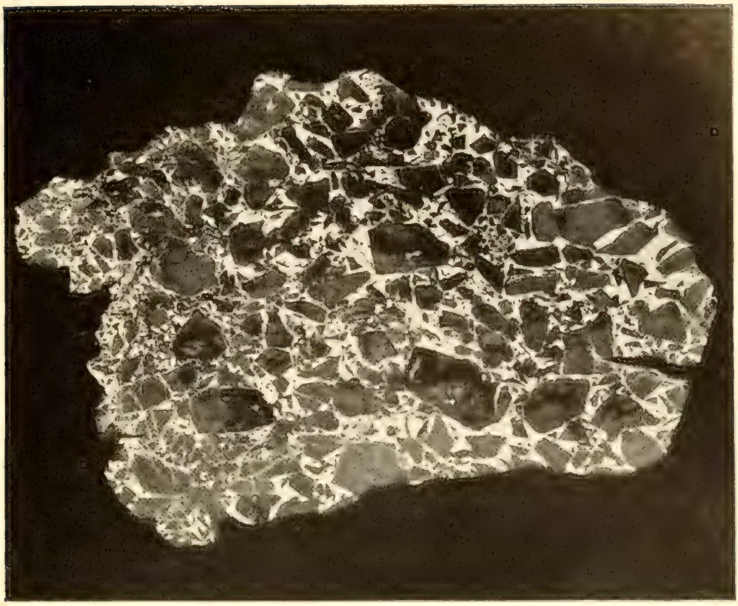
Etched surface of a slice from the Casas Grandes Meteoric Iron

been forced up in a molten condition from unknown depths and intruded into and between the beds of overlying rocks. Their mineral nature is essentially the same as that of the meteorites excepting that they frequently have undergone more or less alteration in which water and oxygen have taken a leading part, and contain no unoxidized metal. A striking and almost sensational similarity lies in the fact that they are sometimes diamond-bearing, as are also meteorites though, so far as now known, only on an almost microscopic scale. The world's supply of diamonds both in South Africa and the United States comes from terrestrial peridotites. How widely separate the stony meteorites and peridotites are from the rocks of the earth's crust, taken as a whole, is shown in column 3 of the last table. It will be noted that the meteorite is some 20% lower in silica, 11% lower in alumina, 12% higher in metallic iron, and nearly 20% richer in magnesia. It is therefore evident that, so far as shown by the exterior crust, the earth could never have originated from an agglomerate of meteoric matter of a nature of that coming today. One can only assume that the meteorites now falling are of a quite different type from those of the geological yesterday; or else, as seems probable, the exterior portion of the earth has undergone an extensive alteration and its true meteorlike nature is to be learned only by borings many thousands of feet in depth. There have thus far been found among meteorites no rocks resembling granite and the more acidic igneous rocks, nor of gneiss, schist, limestone, sandstone, nor indeed any of the great series of sedimentary and metamorphic rocks of which the earth's crust is composed. Nor has there yet been found anything truly suggestive of the one-time presence of organic life. The statement once made that our earth if broken up would yield materials of a meteoric nature is only to a certain extent true, for it would yield also a vast amount of material of a nature wholly unlike known meteorites.

In the preceding pages we have set forth something of the chemical make-up of the several classes of meteorites. The physical condition and arrangement in the mass of these various constituents is interesting and at times radically different from that found in terrestrial rocks. Indeed the conditions are so marked that one versed in the subject can often pronounce at once regarding the meteoric character of a submitted stone, even though not seen to fall, and without the aid of chemical or microscopic tests. As it would be very difficult to give a clear impression of the curious structures found in meteorites by word description alone, the reader is invited to consult carefully the illustrations of this chapter, which reproduce photographs made with the microscope.

1. The All-Metal Meteorites: Siderites

Metallic meteorites, as has been stated, are composed almost wholly of iron with a small and variable percentage of nickel. In the main, these metals are combined in meteorites to form two alloys, named respectively kamacite and taenite. Each of these alloys, in nine metallic meteorites out of ten, is likely to occur in the form of thin plates separated by irregular portions of a third alloy called plessite which fills the interstices. Now the characteristic feature of the matter is that the thin plates of kamacite and taenite tend to lie parallel to the faces of a possible octahedron such, for example, as might be formed by putting two pyramids, in shape like the great pyramids of Egypt, base to base. Figure 7 is used to show the appearance of these markings as dependent upon the angle at which the section is cut. To reveal this structure clearly, as shown in Plate 18 (which is from the 3,000-pound mass of the Casas Grandes iron) it is necessary to cut and polish a flat surface and etch it with dilute acid. Such markings are called Widmanstätten figures, after their discoverer. In thick-



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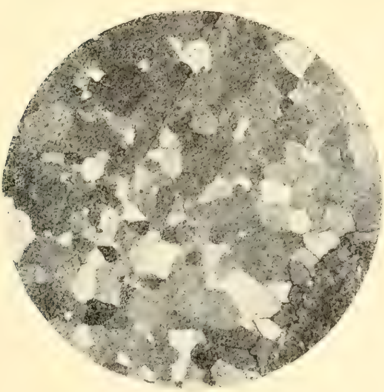

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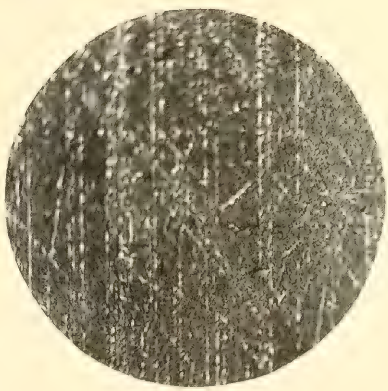
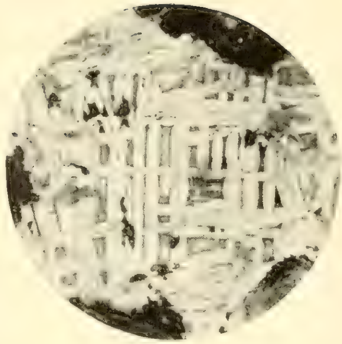


3

(1) A polished surface of a fragment of the Admire, Kansas, pallasite.
(2 and 3) Granular and hexahedral structure of meteoric irons

I



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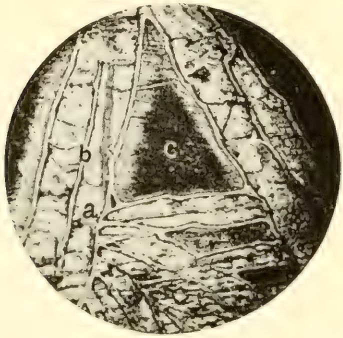

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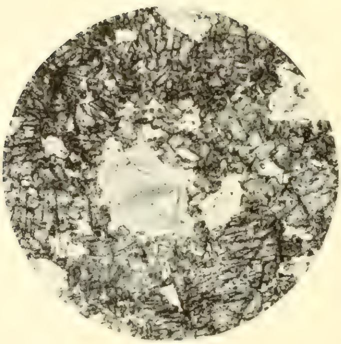

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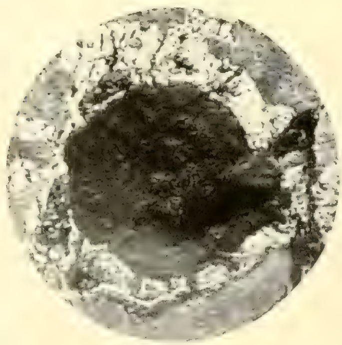


5

(1) Dendritic schreibersite in Arispe iron. (2) A polished and etched surface of the Mesa Verde iron. (3) Enlarged Widmanstätten figures showing arrangement of kamacite, taenite, and plessite. (4) A micro-section of the Estherville stony-iron. (5) A nodule of carbon with halo of schreibersite

ness the plates vary from the fraction of one to several millimeters, which fact forms the basis of their separation into *fine octahedrites* (Of), *medium octahedrites* (Om), and *coarse octahedrites* (Og), etc. (See under *Classification*, page 112.) At times the kamacite plates assume broad and irregular forms, as in the iron of Ainsworth and New Baltimore, which predominate over all other constituents

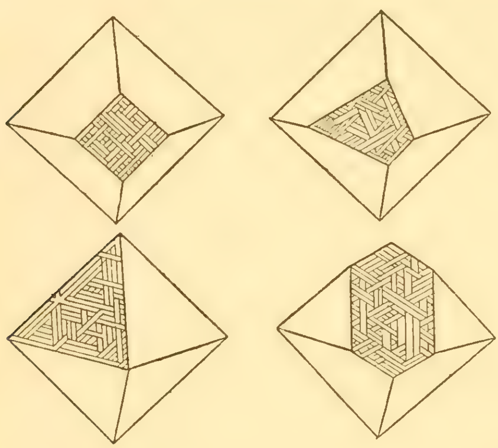


FIG. 7. Diagram showing Widmanstätten figures as appearing when an iron is cut at varying angles

and in which the octahedral structure is wholly undiscernible except on large surfaces.[3]

Not all irons show the octahedral structure. In some the alloys occur in the form of granules so fine as to escape easy notice and thus to appear of a noncrystalline structure, or, as we say, amorphous. These irons show on etching only certain faint parallel lines traversing the surface, which are due, according to Neumann, of Vienna, after whom they are named, to the union of crystals in

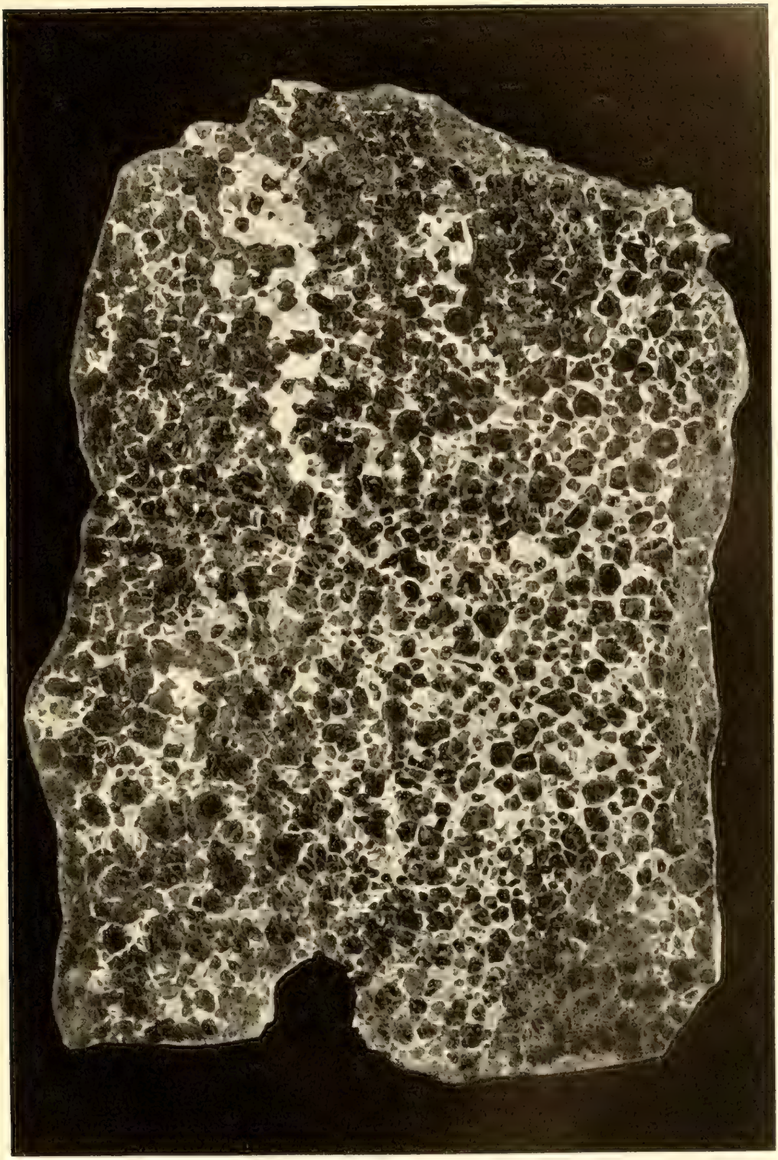
[3] Farrington's tabulation of analyses seems to show that the texture varies with the nickel content, the finest crystallization being found in irons richest in nickel. The ratio is, however, by no means constant. (*Field Museum Pub.* No. 120, 1907.)

definite opposed relations technically known as twinning, and in this case parallel with the faces of a cube (Plate 19, Figure 3). Still other irons are distinctly granular, a structure which, as shown later, may be due to the action of heat. The systematic regularity of arrangement of the taenite and kamacite plates which form the chief constituents of an iron is often interrupted by the presence in minor quantities of various accessory minerals, as cohenite, schreibersite, and troilite, or carbon nodules which are as a rule distributed without order or, it may be, in an octahedral iron, lying parallel with the kamacite bands. (Plate 20, Figures 1 and 5.)

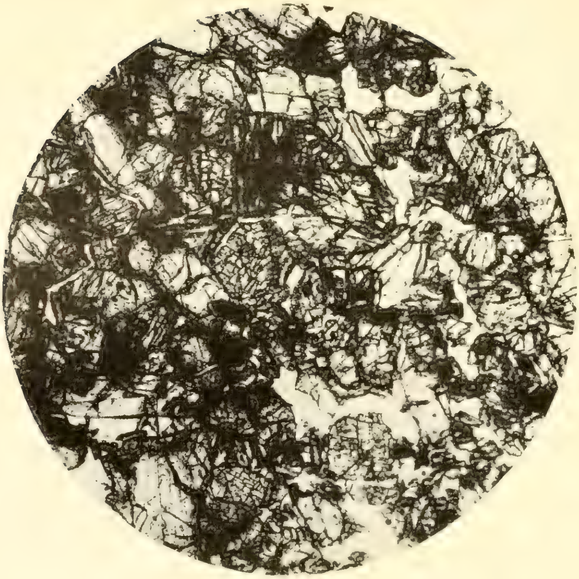
The interest of the structure is often enhanced by the diffusion of the mineral schreibersite in the so-called dendritic, or treelike forms, or as halos about nodular masses of graphite or carbon. Or, less strikingly, it may be disseminated in the form of plates or granules. The troilite occurs in granular irregular forms diffused through the iron, or in nodular masses admixed with carbon (see Plate 18) and at times in long thin lamellar forms lying parallel with the faces of a possible cube. These last forms were first recognized by Reichenbach and were named Reichenbachian lamellae by Tschermak. All these can be best understood by reference to figures in the plates.

2. Stony Iron Meteorites: Siderolites

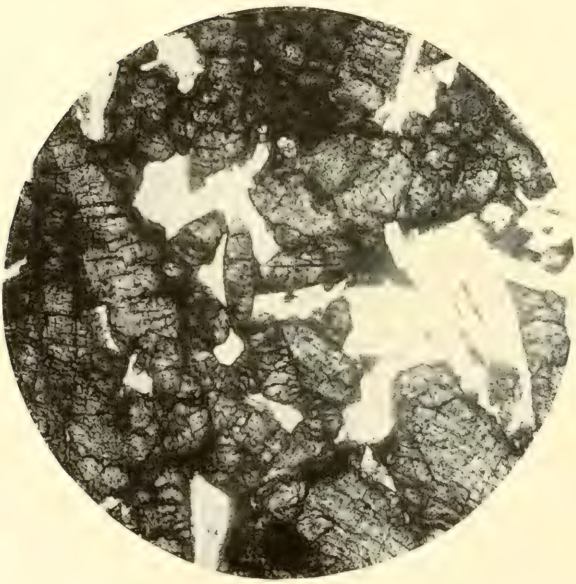
Plate 21 is from a stony iron of the variety named pallasite after Peter Simon Pallas, a German naturalist whose famous scientific journey through Russia and Siberia under the patronage of the Empress Catherine II, on the occasion of the transit of Venus in 1769, formed the subject of a beautifully illustrated series of volumes which were translated into French and English. The specimen figured was found some years ago at a locality known as Mount Vernon, in Christian County, Ken-



A polished slice of the Mount Vernon, Kentucky, pallasite



1



2

Figures showing the structure of the (1) El Nakhla and (2) Shergotty meteoric stones tucky. The light-colored netlike portion is composed of nickel-iron alloys identical in composition, so far as now ascertained, with those of the all-metal meteorites. The dark areas are silicate minerals—in this case olivine (peridotite). The structure has been compared, not inaptly, to that of a sponge in which the original sponge material is metal, the silicates filling the meshes. Meteorites of this type are somewhat rare, only about twenty now being known. It is to be noted that the metal, wherever surfaces of sufficient size are exposed, shows a tripartite structure and is never granular. Further, that the kamacite bands often surround the olivines in a form known as *swathing* kamacite, or white iron, on account of its color and brilliant reflection. Between the kamacite and plessite is often a thin band of taenite as in the all-metal forms.

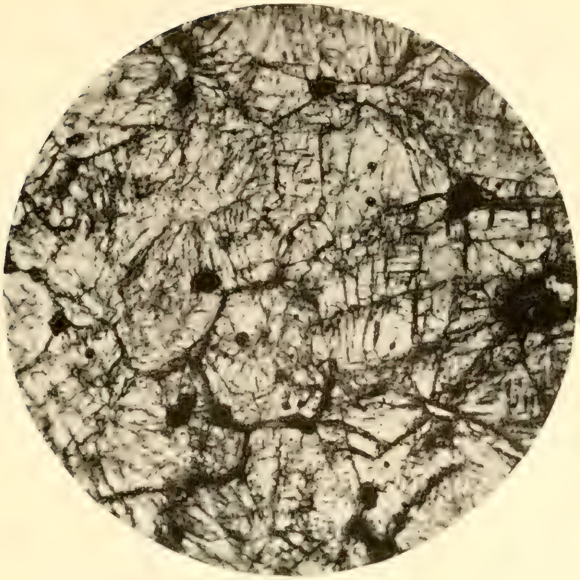
Interesting varietal phases of the pallasites are shown in Plate 19, Figure 1, where are aggregates of sharply angular silicate minerals imbedded in the metal like crushed stone in a cement floor. It is difficult in the present state of our knowledge to account for these forms excepting through pressure and shearing.

3. Stony Meteorites: Aerolites

The formulation of a satisfactory description of the internal structure of the stony meteorites is a matter of considerable difficulty, this in part owing to their confused and heterogeneous character. One might say that they were indescribable in words, at least in a manner that could be understood; hence recourse is made to ocular demonstration. For those unversed in modern methods of research it may be well to state that the methods pursued are essentially the same as with terrestrial rocks. A small fragment of the meteorite is ground smooth on one side and cemented with Canada balsam to a slip of glass, after which it is ground so thin as to be transparent, the slip of glass serving simply to hold the object while grinding and prevent its breaking. By means of an especially designed microscope it is then possible to determine the nature of the individual constituents and their arrangement one with another. The figures shown here are from photomicrographs made from these "thin sections" as they are called.

The one great difficulty in the determination and description of meteoric minerals lies in their imperfect crystalline development and shattered and often discolored condition caused by the oxidation of the lawrencite, troilite, and metallic portions. Many meteoric stones are plainly products of a somewhat hasty crystallization from a molten condition; few show the wholly crystalline structure due to gradual cooling, as in many terrestrial igneous rocks. Many, since cooling, have been shattered throughout from causes not yet wholly apparent, but probably by collision or rapid transitions from great heat to a corresponding cold. Still others are seemingly made up of recompacted dust and sand such as might result from the trituration of rock fragments in a volcanic throat, as happens in modern volcanoes, giving rise to a class of rocks known as *tuffs*. The individual particles may be of microscopic dimensions or in the form of recognizable fragments, as in Plate 17. The matter is further complicated by sundry changes, due to heat, which have taken place subsequent to this reconsolidation. Indeed the confused structure shown by many meteoric stones has given rise to an equal confusion on the part of students as to their causes.

Few meteoric stones, probably not over a score of those now known, show the crystalline structure characteristic of terrestrial igneous rocks, either basalts or peridotites. Such are best represented by the stones of Shergotty, India; El Nakhla, Egypt; and Chassigny, France; the first being much like a basalt, the second a pyroxenite and the third a peridotite. Still others are



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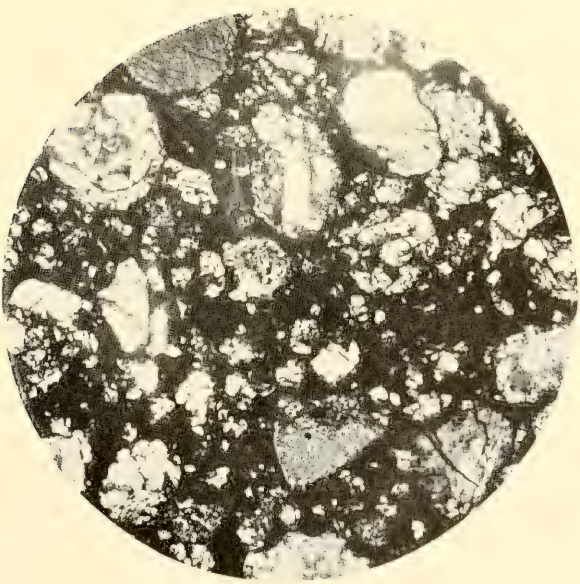


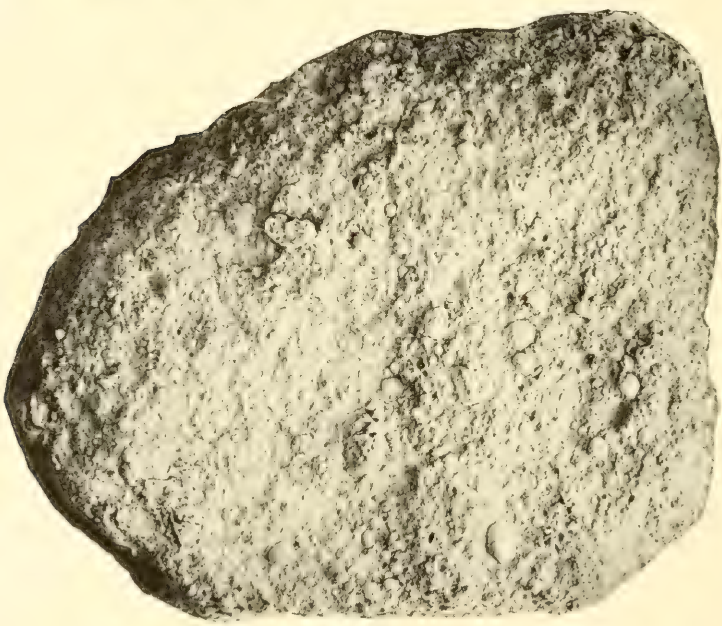
2

Figures showing the microstructure of the (1) Chassigny and (2) Selma meteoric stones

PLATE 24

1

2



3

Figures 1 and 2. Chondrules and chondroidal forms from the Bjurbole stone, and (3) a broken surface of the same stone showing chondritic structure made up of fragments of rocks, once crystalline, but broken up and recompacted. (Plates 22 and 23.)

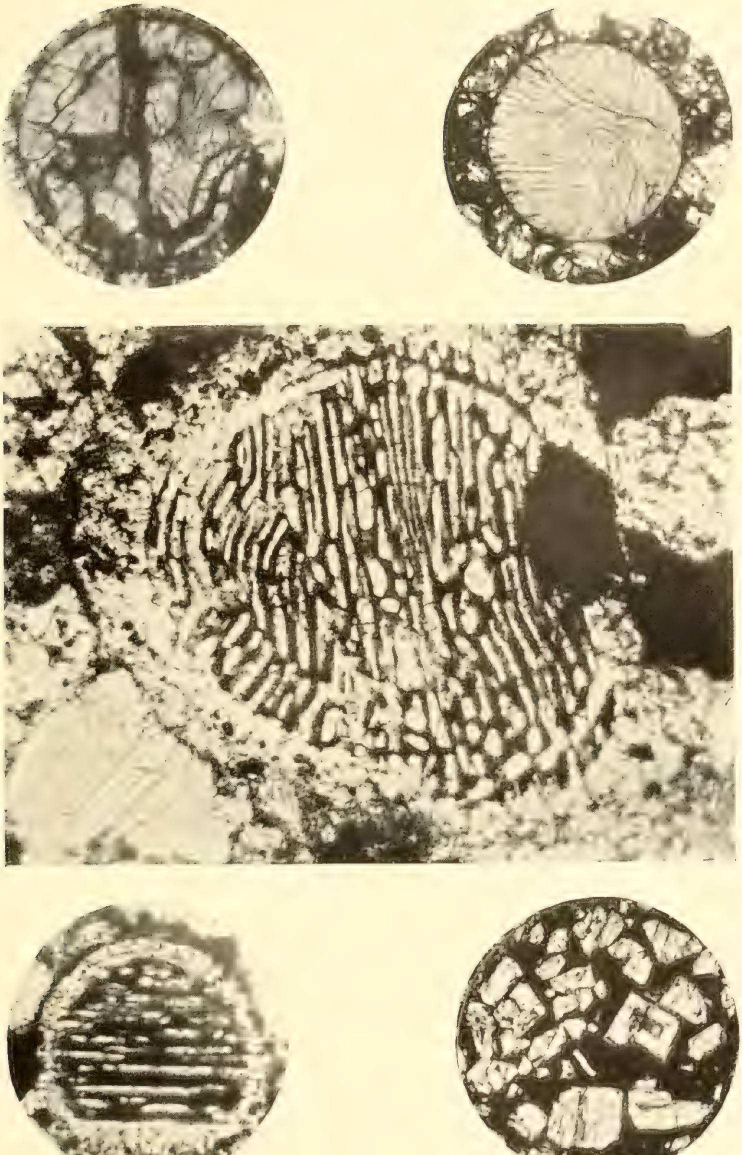
Fully ninety per cent of the known meteoric stones are made up of volcanic dust and sand as mentioned above and may be described as tuffaceous, or as tuffs. These are almost invariably characterized by the presence of small spherical, shotlike bodies called *chondrules* from a Greek word meaning *grain*, and the stones containing them *chondrites* for the same reason. This is a structure the exact counterpart of which has not been found in terrestrial rocks and the formation of which affords not only a distinctive characteristic, but in connection with their origin has been the cause of one of the most interesting and controversial questions relating to the subject in general. The structure of a typical chondritic meteorite, a *spherulitic chondrite* as it would be called, is shown on Plate 24. Stones of this type are often so friable as to be readily crushed, allowing the chondrules to become detached, as shown in Figures 1 and 2. In other cases they are held so firmly as to break with the matrix, when they appear in the thin section described above, as shown in Plates 25 and 26. Such interesting and peculiar forms are now known to be due to the cooling and partial crystallization of molten drops of stony matter; mineralogically they are mainly olivine and enstatite. Nevertheless, before their true nature was known, they were thought to be the remains of small organisms and were described as corals, crinoids, and problematic organisms. Their origin has been made the subject of much discussion and wordy warfare among students, but the matter need not be gone into further here. Those who have seen the Bessemer converter used in steel manufacture in operation, with the molten drops being blown from its mouth, will gain an idea of at least a possible method of their origin.

Occasional meteorites of this tuffaceous and chondritic type show signs of changes subsequent to their consolidation which are comparable to a form of metamorphism produced in terrestrial rocks by heat. This is due to a partial refusion of certain constituents. A discussion of these changes will, however, lead us too far astray for a work of this nature, so we may well stop here, with but a backward turning to the subject of meteoric irons. In Plate 27, Figure 1, is given a view of an etched surface of the iron of Toluca, Mexico, and in Figure 2 an etched surface of the same iron after it had been heated for some hours at a red heat in an ordinary coal fire. It will be noted that the characteristic octahedral structure has been partially obliterated by granulation. Berwerth, an Austrian worker who has carried on experiments in this line, states that by prolonged heating the octahedral structure can be made entirely to disappear and the iron to become granular throughout. This naturally brings up the question of the possibility that all the granular irons were once octahedral forms that have been changed by heating. Here again we get into too technical a phase of the subject and may stop with only a reference to the possibility that all the metal in stony meteorites may be secondary and due to the reduction of a ferrous chloride introduced in a liquid or gaseous condition subsequent to, or contemporaneous with the consolidation of the stone.

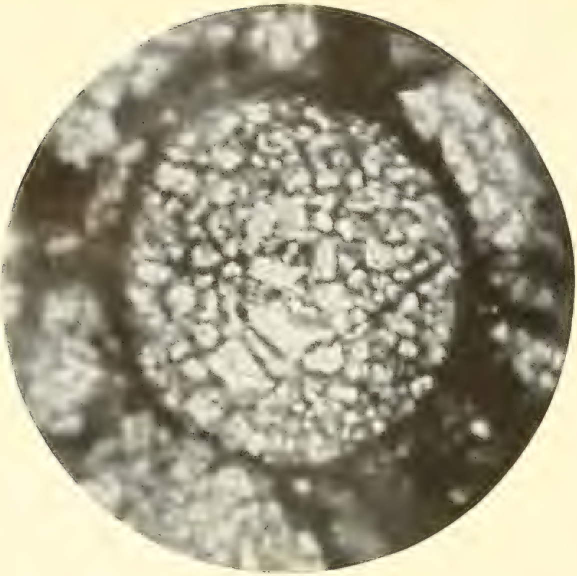
4. The Earth as a Meteorite

As long ago as 1848, the Frenchman, M. Boisse, pointed out the probable physical structure of a giant meteoric or cometary mass. He argued that, were one of these bodies brought into a condition of such fusion that the elements could group themselves according to their chemical affinities, the mass, on cooling, would assume a spherical form in which the constituents would be arranged according to their gradually decreasing densities. There would then be a metallic center, or core, of nickel-iron, surrounded by a zone of mixed ferruginous silicates and metal, and this in turn by zones of the lighter silicates,

PLATE 25



Five views of chondrules from various meteorites, as shown in thin sections



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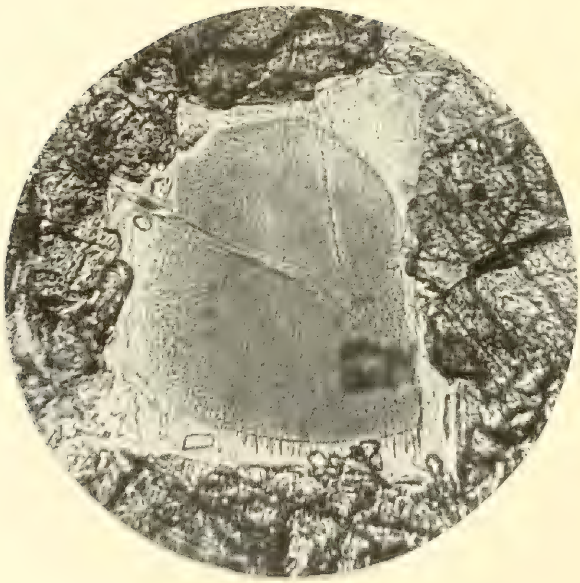


2

1. A chondrule in the Parnallee meteoric stone, showing a secondary glassy border. 2. Feldspar in the Estherville meteorite showing partial refusion

each grading into the next and becoming gradually metal-free. The same idea as to *earth* composition and structure has long been prevalent. Meunier, of Paris, elaborated it in 1867, and later Prior, of the British Museum, has given it a modern interpretation. According to the last-mentioned, the central earth core, while consisting essentially of nickel-iron, would carry also small quantities of unoxidized magnesium, calcium, sodium, aluminum, and chromium, with the nonmetals, silicon, sulphur, and carbon. Beyond this would be a zone in which these same elements occur, partly metallic and partly in the form of oxide compounds of magnesium, silicon, sodium, aluminum, and calcium (pyroxene, olivine, etc.), comparable to meteorites of the pallasite type. Beyond this again would be still other zones, of gradually decreasing densities, composed of the highly oxidized and less ferriferous silicates, comparable with the stony meteorites or aerolites, ultimately passing into rocks of the basaltic type, from which, through weathering, decomposition, and complex metamorphism, have been derived those forming the present surface features.[4] The subject offers an interesting field of speculation, but is quite beyond our field of discussion, unless one chooses to go to the extreme of considering the earth itself a giant meteorite.

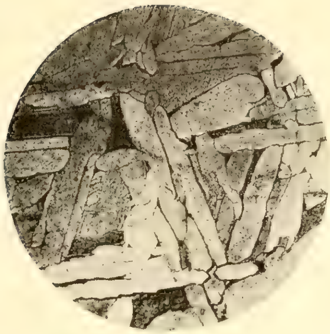
"Il n'est pas malaise d'inférer de tout ceci que la Terre et les cieux sont faits d'une mème matière." [5]

We should like, with Arrhenius, to think of a world new-born and barren, to which the seeds of life might be borne by a swift-flying meteor; a life which, however humble in its beginning, might develop through countless years into forms as high and perhaps even higher than our own. Fascinating as such a thought may be, how-

[4] V. M. Goldschmidt, and later Adams and Washington (*Zeit. Elektrochem.*, Vol. 28, 1922, and *J. Washington Acad. Sci.*, Vol. 14, No. 14, 1924) have discussed the matter with very like conclusions.

[5] Descartes, quoted by Daubrée.

ever, it is based upon but flimsy foundations. Not only are our meteorites of materials little likely to contain possible animate matter, but the very conditions through which they pass, from the cold of space to the fiery proximity of the sun and the final scorching plunge into an atmosphere like ours, are all against the survival of organic life even if it once existed.



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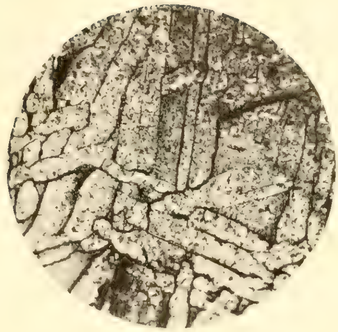

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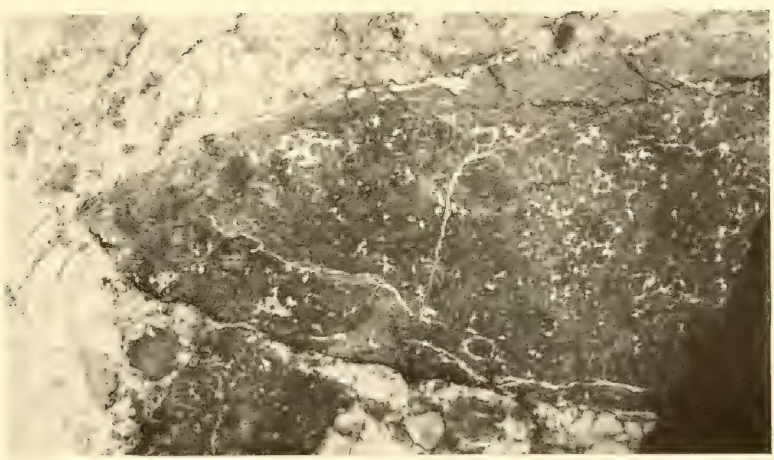


3

Two figures showing the structure of the Toluca meteoric iron, before and after heating, and (3) a polished surface of the Cumberland Falls meteoric stone showing the distribution of the iron

CHAPTER VI

NAMES AND CLASSIFICATION

WHAT'S in a name? Apparently not much in the mind of him who raised the question. But conditions alter cases. Sometimes much depends on the name. It furnishes at least a handle by which to take hold—something to fix in mind that which one is writing or talking about.

In the early days, before their nature was fully understood, various names were given to meteorites, based upon conditions attendant upon their falling or other natural causes, regardless of their mineral nature. *Shooting stars*, *bolides*, *fireballs*, *thunderstones*, *uranolites*, and *skystones* are among the more common, and of which each language furnished its own equivalent. The term *aerolite* is stated to have been applied by Blumenbach as early as 1804, and the distinction between stones and irons was likewise early made apparent in the nomenclature. It was not until 1863 that Prof. H. Story Maskelyne made the present accepted division into (1) aerolites, (2) aerosiderolites, and (3) aerosiderites, names now generally shortened into aerolites, siderolites, and siderites, designating the stony meteorites, stony-iron meteorites, and iron meteorites, respectively. Gustav Rose in 1862 made the suggestion, now generally adopted, that the finer subdivisions of meteoric stones be based upon mineral composition and structure; and divided them into chondrites and achondrites accordingly as they did or did not carry the peculiar rounded bodies known to the Germans as *Kugeln*, but to the English as chondrules. From these early beginnings has been evolved what is called the Rose-Tschermak-Brezina classification here tabulated. The French authority, Meunier, also evolved a scheme which has, however, failed of so general an adoption by European and American workers.

Meteorites are named after the locality where they fall or are found, as *Allegan*, *Bustee*, *Weston*, etc., each of which represents a post office or other geographic subdivision of sufficient importance to be found on any detailed geographic map or comprehensive gazetteer.

At first thought this system may seem inexact and unscientific. As a matter of fact it has been found to work well in practical application, and leads to little confusion. The old saying that "lightning never strikes twice in the same place" may with equal proximity to accuracy be said of meteorites, no two falls being recorded from the same area. The main objection to the system thus far developed lies in the wide extent of certain falls, as that of Estherville, Iowa, and occasionally the lack of a precise geographic name, as in regions remote from human settlement.[1] In such cases the latitude and longitude are, or should, always be given, together with the nearest named locality. The advisability of a geographic and also a time record, in case of an observed fall, lies in the necessity for data in the study of the probable ultra-terrestrial source from which the meteorite may have come.

In classifying meteorites, recognition, as stated, is given mainly to the internal structure and mineral composition. Obviously mode of occurrence and source can not be given consideration as among terrestrial rocks.

[1] A good illustration of this is offered by the so-called Four Corners meteorite. The gazetteer and post-office directory recognize no such locality. But the iron was found in New Mexico near the intersection of the boundary line of Arizona, Colorado, New Mexico, and Utah. There is no similar instance in the country, and the same is felt to be sufficiently distinctive. All attempts at naming meteorites after individuals—at "creating a progeny for the childless," as is done in mineralogy and biology—have failed. The workers will not accept them.

Chemically all belong to the basic divisions of terrestrial rocks and would fall within the basalt-pyroxenite-peridotite series. The attempt recently made to classify the stony meteorites under the "quantitative system" of the modern petrographers cannot be considered satisfactory, since it is based wholly upon chemical analyses and resultant theoretic mineral composition. The two systems which have met with most widespread acceptance are those gradually evolved from the work of Rose, Tschermak, and Brezina, already mentioned, and of S. Meunier. In both systems the three primary subdivisions already noted are based upon the relative preponderance of the stony and metallic constituents. These are again subdivided according to the chemical nature of the prevailing silicates and their structure. The main divisions are:

Aerolites or stony meteorites	Consisting essentially of silicate minerals with minor amounts of the metallic alloys and sulphides.
Siderolites or stony-iron meteorites	Consisting of an extremely variable network or sponge of metal, the interstices of which are occupied by the silicate minerals.
Siderites or iron meteorites	Consisting essentially of an alloy of nickel-iron with iron phosphides and sulphides.

The detailed classification will be found in Appendix I.

CHAPTER VII

WHENCE DO THEY COME?

We come now to the question of the ultimate source and origin of these interesting and remarkable bodies. Naturally the striking character of the phenomenon of a falling meteor would serve to excite the dullest imagination, while the range of seeming possibilities is so great as to tempt flights from the known far into the unknown, even into realms where the wildest imagery can be freely indulged without fear of disastrous collision with solid fact.

The problem is largely an astronomical one, as may be readily understood, as may also the fact of its difficult solution. Observations of individual meteors are numerous, but are necessarily of such brief duration as to render them in most cases of doubtful value. That portion of our information for which we may claim approximate certainty is that relating only to the closing chapter in what may be called the life history of a meteorite. We may theorize over the ultimate source, and even on the origin of matter itself; from observations of speed and orbit, we may gain an approximate idea of the portion of space whence it was derived; but only in the meteorite itself do we have a tangible actuality which may be studied at leisure.

Let us consider in an historical way some of the more plausible of the theories thus far advanced. The path to solution may seem at times blind and devious, but leads nevertheless toward a clear understanding of the matter.

First, as an example of the numerous theories—flights of the imagination I could almost call them—let me quote from a summary of them by Professor Newton:

> They came from the moon; they came from the earth's volcanoes; they came from the sun; they came from Jupiter and the other planets; they came from some destroyed planet; they came from comets; they came from the nebulous mass from which the solar system has grown; they came from the fixed stars; they came from the depths of space.

Fortunately not all of these suggestions are of sufficient probability to merit attention today.

It was Chladni who, more than a hundred years ago, advanced the idea that meteorites are but the remnants of cosmic matter employed in the formation of worlds. He looked upon comets, falling stars, meteoric fireballs, and meteorites as all of a similar elementary constitution and origin. Though more recent students may be inclined to regard his conclusions as a series of lucky guesses, the fact remains that subsequent investigation has shown him to have been essentially correct in many of them. If, however, worlds like ours, as we know it, have been formed from meteoric aggregates, we must conclude that the meteorites of the past, while, it may be, composed of the same kind of elementary matter, held it in quite different proportions, since the most abundant of known world materials are, as has been shown, among the least abundant of meteoric substances.

Astronomers tell us that in the far reaches of space beyond our solar system are dark nebulous clouds which obscure the more distant stars, as nearer stars are obscured by thin clouds of vapor. What may be the nature of these clouds is wholly speculative. That they are not water vapor and have nothing to do with our atmosphere is certain. May we not with a fair degree of assurance assume that they are composed of fragmental—discrete—matter like the ejectamenta of a modern volcano, and that in time this will be gathered in as meteoric matter by neighboring planets? With the aftermath of sunglows caused by dust from Krakatoa in mind, this should subject a facile imagination to no serious strain, and a world free-floating and slowly augmenting its bulk through the ingathering of waste from space is a fascinating vision. From such a conception we are somewhat rudely awakened by Chamberlin who now considers the idea that planets have been formed by infalls of scattered meteorites as "an old and practically abandoned theory."[1]

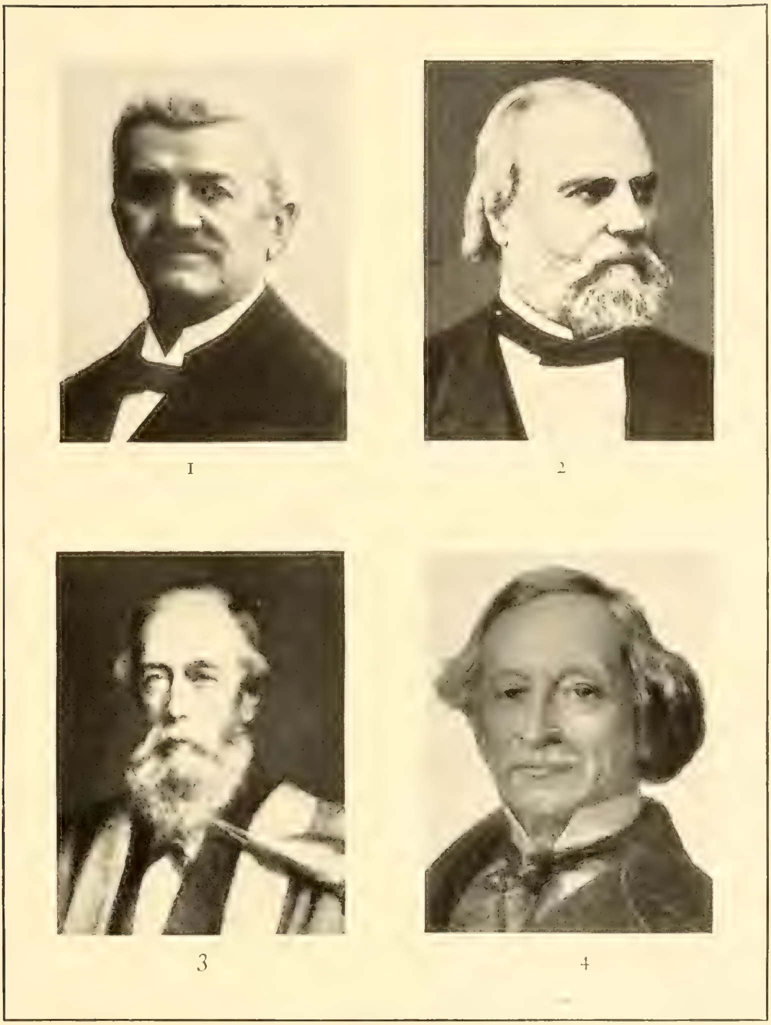
Wilhelm Olbers, another of the early workers, considered for a time (1795) the possibility of meteorites having been ejected from lunar volcanoes.[2] This view was accepted by Lichtenberg, who remarked incidentally that "the moon was an uncivil neighbor for throwing stones at us." No less an authority than Laplace gave it favorable consideration.[3] As the attraction of gravity at the surface of the moon is much less, only about one-sixth that of the earth, and as it has no atmosphere, it was conceived possible that by explosive volcanic action a body might be so far projected into space as to pass quite beyond gravimetric recall and become a satellite of the earth, about which it would revolve in a more or less elongated orbit until, its speed sufficiently retarded, it would fall with all the attendant phenomena of a meteorite. This view, with various modifications, has been adopted by several of the more recent workers, among whom mention should be made of J. Lawrence Smith who wrote as late as 1885, and with pleasing certainty: "There is not a single evidence of the identity of shooting stars (as exemplified in the periodical meteors of August and November) and those meteors which give rise to meteoric stones." He argued that all meteoric masses had a common origin and at one time formed parts of some large body; that all had been subjected to more

[1] The genesis of planets. *Yearbook Carnegie Institution*, 1924, p. 273.

[2] According to Phipson this idea was first put forward by Paolo Maria Terzazo in 1664.

[3] "It is not impossible that large masses detached from some of the celestial bodies, and particularly from the moon, may have sometimes been projected to the earth." (Laplace, quoted with approval by Olbers, *Tilloch's Magazine*, May, 1803.)

PLATE 28



(1) F. Berwerth; (2) J. L. Smith; (3) H. C. Sorby;
(4) C. U. Shepard

or less prolonged igneous action, corresponding to that of terrestrial volcanoes, and that they possessed the average specific gravity of the moon. His conclusions at this date he summed up as follows:

> It may be stated that the moon is the only large body in space of which we have knowledge possessing the requisite conditions demanded by the physical and chemical properties of meteorites. They have been thrown off by volcanic action or some other disruptive force and encountering no gaseous medium of resistance have reached such a distance that it no longer exercises a preponderating attraction. The deported fragments, having in common with the moon itself an orbital velocity now more or less modified by the projectile force and new conditions of attraction in which they have been placed with reference to the earth, acquire an independent orbit more or less elliptical. This orbit, subject to great disturbing influences, sooner or later passes through our atmosphere, and the flying fragments are intercepted by the body of the globe.

Thus plainly and seemingly conclusively the problem was solved.

Plausible as these views may have seemed at the time, it has been contended by others that it is impossible that a body the size of the moon could contain volcanoes of sufficient projective power to produce these results; and, further, it was shown in 1859, by the calculations of B. A. Gould, that even were bodies thus thrown out, there is not one chance in two million that one of them would ever reach the earth as an aerolite.

In 1811, the astronomer Olbers, whose transient views have been mentioned, came forward with a new suggestion which for some years received favorable consideration. He regarded the asteroids Ceres, Juno, Pallas, and Vesta, as the principal remains of a large planet revolving between Mars and Jupiter, which had burst into fragments through some internal (and unaccountable) explosion. The smaller of these fragments he thought to have continued their revolutions about the sun, in an eccentric orbit, until, coming within the attractive limits of the earth, they were precipitated as meteorites. As the astronomer Young has stated, granted the explosion,[4] there is nothing improbable in the hypothesis.

H. C. Sorby, from a study of the microscopic structure of stony meteorites, was led to consider it extremely improbable that they were derived from the moon or a planet which differs from a large meteorite in having been the seat of more or less modified volcanic action. His views, it will be observed, had more to do with *conditions* than with actual source. He believed that the constituents of meteorites were originally in a state of vapor such as now exists in the atmosphere of the sun. This, on cooling, condensed into a sort of cometary cloud formed of small crystals and minute drops of melted stony matter which afterwards became more or less crystalline. This cloud being in a state of great commotion, the particles moving with great velocity were often broken by collisions among themselves. The particles thus formed were subsequently collected into larger masses and by heat of impact underwent a more or less complete metamorphism whereby their original nature became quite obscured.[5] In the meantime, the metallic constituents were introduced in a state of vapor and condensed in the interstices of the silicates, as we now find them. The occasional presence of hydrocarbons was thought to be due to a condensation of vapors at a later period.[6] "I therefore conclude," he wrote, "provisionally, that meteorites are records of the existence in planetary space of physical conditions more or less similar to those now confined to the immediate neighborhood of the sun, at a period indefinitely more remote than that of the occurrence of any of the facts revealed to us by the study of geology—at a

[4] That such an explosion is possible seems to be shown by recent observations on the star Nova Poctoris in 1925.

[5] See also under origin of chondritic structure, page 75.

[6] It has since been shown that the presence of hydrocarbons in meteorites is very doubtful.

period which might in fact be called preterrestrial." It may be inferred from this that he regarded their source as interplanetary.

Prof. C. U. Shepard, one-time assistant chemist at Yale University, and one of the most enthusiastic of American students and collectors of meteorites, inclined to the belief that the material of which they are composed was of terrestrial origin; that it had been, while in a gaseous condition, blown by explosive volcanic action beyond the limits of our atmosphere, where it was sustained by magneto-electric forces; and that a meteorite fall was as much to be expected from a disturbance of these forces as would be a shower of rain from similar causes. Wastman, as quoted by Galloway,[7] makes a like lucid (?) suggestion. "The meteors probably owe their origin to the disengagement of electricity or some analogous matter, which takes place in the celestial regions on every occasion in which the conditions necessary for the production of the phenomena are renewed." Shepard's view was not generally accepted, though the idea that the explosive force so frequently mentioned might have been volcanic and in the nature of a terrestrial volcano, as often suggested, was firmly adhered to as late as 1883 by the French astronomer, C. Flammarion. "The greater part of the stones that fall from the heavens were originally of the earth and have been thrown into space by volcanic eruptions in primitive times," he wrote.[8]

Stanislas Meunier, of the Paris Museum of Natural History, and a prominent student of meteorites, also inclined to the belief that meteorites were formed under conditions similar to those which have existed in the past upon our earth; but that those now coming to us are from a one-time existing satellite, smaller than the moon, which, having already passed through the stages of planetary evolution, has been resolved into fragments which

[7] *Edinburg New Philos. Journ.*, Vol. 30, 1841.

[8] L'Astronomie, Vol. 2, 1883, p. 141.

are gradually falling back once more upon the body from which they were originally derived.

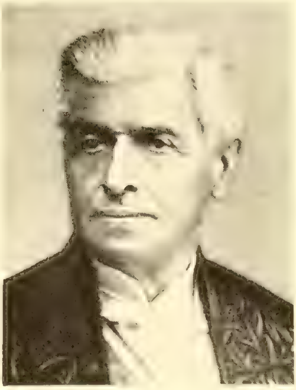
A. Daubrée, at one time a most eminent authority on the constitution of meteorites, was disposed, with Olbers, to regard them as products of the disintegration of asteroids, as the result of an explosion, or more commonly of a violent shock, as a collision. "The meteorites which fall upon our planet," he wrote, "illustrate one of the changes which are going on in space through the distribution of the '*débris* of demolition' of certain stars or asteriods among other stars."

The Austrian, Gustav Tschermak, than whom there were few better authorities concerning composition and structure, writing in 1875, called attention to the fact that the form of meteorites "is likely to afford some insight as regards the antecedents of the masses whence they are derived." He agreed with the German, Haidinger, that each meteorite as it enters our atmosphere is a fragment and owes its form to a disruption of a larger mass, although he did not lose sight of the fact that many meteorites are broken further by the resistance of the atmosphere during their fall. Briefly stated, he concluded that "it would then appear that the material of which meteorites consist has been furnished by one or more large masses, the formation of which must have occupied a long period of time."

With Daubrée's idea of disintegration by impact (*i.e.*, collision) Tschermak did not agree but thought it much more probable that, to whatever degree such disintegration had been carried, it had been brought about by a force acting from within outward—in short, by an explosion. In other words, he seemed to regard the evidence of volcanic activity found in the tuffaceous and chondritic structure of a meteorite proof of explosive force sufficient to account for the gradual destruction of the original body, whatever its nature or mass. Berwerth,

PLATE 29

1



2

3

4

(1) S. Meunier; (2) A. Daubrée; (3) G. Tschermak; (4) D. Olmsted

1

2

(1) H. A. Newton; (2) Norman Lockyer

likewise of Vienna, writing as late as 1907,[9] favored the explosive hypothesis. He felt that all the circumstances point to successive explosions from a celestial body of considerable size but not of sufficient gravimetric attractive power to draw back to itself the ejected fragments. Through these successive explosions the body itself would become more or less completely resolved into fragments that now, in various routes, are traversing space.

Among the recent speculations relative to the origin of meteorites, mention must be made of those of Prof. T. C. Chamberlin and Prof. W. H. Pickering. The first named, considering their origin through the disruption of small planetary bodies, suggests that the fragmentation may have been brought about without actual collisions between themselves, but by the disrupting action of attraction when two bodies of sufficient mass and density come near to one another, *i.e.*, within the "Roche limit," as it is called. Bodies thus disrupted, so long as their fragments remained clustered, would form comets, but when dispersed by approach to another body of sufficient attractive force, might constitute meteorites. Professor Pickering suggests that, as an alternative hypothesis, the stony meteorites may be considered as formed "during the great cataclasm that occurred at the time the moon separated from the earth." That when the pressure on the deep-lying portions of the earth was suddenly relieved through the flying off of the upper layers, now forming the moon, considerable portions of our atmosphere must have followed the larger flying masses, which would so retard the smaller that they in part failed to escape the attractive power of the earth. These, flying in constantly shifting orbits due to perturbations caused by proximity of the earth and moon, would ultimately pass near enough to one of these bodies to be torn to pieces, in the manner suggested by Chamberlin, and ultimately find their way back to earth as meteorites.

[9] *Sitz. der Kais. Akad. der Wiss.*, Bd. cxvi, Abt. ii, 1907.

Here, it will be observed, is a theory based upon a by no means commonly accepted hypothesis.

Almost as a matter of course there was from very early times a supposed direct connection between the meteorites which come so noisily to earth, and the silent, seemingly intangible meteors or shooting stars of the periodic showers. Denison Olmsted of Yale (in 1834) was among the first to raise an apparently well-formed doubt as to this identity. He based these doubts on the lack of apparent time relation between meteor displays and meteorite falls, and in part on the apparently easily combustible nature of the periodic meteors, some of them being thought of a flocculent nature and of the texture of cotton, and even of matter so attenuated as to be almost impalpable. Olmsted, too, was the first to call attention to the fact that the November meteors all emanated from a common visual center, having a focus, since called the radiant point, which is situated in the constellation of Leo. The August meteors, on the other hand, have their radiant in the constellation of Perseus, and those of April in that of Lyra. In the last two cases, it should be mentioned, the radiant points are not stationary, but in rapid motion.[10]

Olmsted's doubts as to the identity of meteors and meteorites were not shared wholly by either his contemporaries or those who came after. Daniel Kirkwood, in his work on *Meteoric Astronomy* (1807), while acknowledging that "no deposits from ordinary shooting stars have been known to reach the earth's surface,"[11] yet believed the two classes of bodies to be coexistent, "that meteoric

[10] The Italian astronomer Schiaparelli calculated that the meteoric stone of Pultusk, which fell on January 30, 1868, came from the constellation of the Great Bear, while that of Knyahinya, which fell June 9, 1866, was from Pisces.

[11] It is to be noted, however, that of the seventeen irons that have been seen to fall, there are two, those of Rowton (1876) and Mazapil (1885), which can be thus relegated, the first with the Lyrid meteors and the second with the Andromedes. In consideration of the known fairly uniform distribution of meteorite falls throughout the year, such can be considered little more than coincidences. (See also page 95.)

stones are but the largest masses in nebulous rings from which showers of shooting stars are derived."

In a lecture delivered at the Sheffield Scientific School of Yale University in 1879, Prof. H. L. Newton, after a review of the general subject, stated:

> Thus we are led to say: First, that the periodic meteors of November, of August, or April, etc., are caused by solid fragments of certain known or unknown comets coming into our air; secondly, that the sporadic meteors such as we can see any clear night are the like fragments of other comets; thirdly, that the large fireballs are only larger fragments of the same kind; and finally, that this stone [a fragment of the Homestead fall of 1879] which was broken off one of those large fragments in coming through our air, must once have been a part of a comet. [12]

And again, in his address before the American Association for the Advancement of Science in 1886, he stated that

> We may reasonably believe that the bodies that cause the shooting stars, the large fireballs, and the stone-producing meteors, all belong to one class; they differ in kind of material, in density, in size, but from the faintest shooting star to the largest stone meteor we pass by such small gradations that no clear dividing lines can separate them into classes.

Essentially the same views are given by Lockyer in his *Meteoritic Hypothesis* (1890) and are very generally adopted. As confirmatory of this hypothetical source, reference is commonly made to the history of Biela's comet. This was first seen in March, 1772, when it was found to be traveling in an eccentric orbit about the sun, including in its course a portion of the orbit of the earth. Since its first discovery and during the residual period of its existence, it has made this journey every 6⅔ years. The last seen of it in its primary condition was in 1832. When it became due in 1839 it was on the opposite side of the sun from the earth and hence invisible. In 1845 it

[12] "All the solar space," writes Olivier, "must be populated by *débris* of comets long since broken up into tiny fragments of their original great volume." (Meteors, 1925, p. 23.)

became visible again, but was broken into two widely separated portions, each with a train of its own. In 1852 it appeared for the last time as a comet, and in 1859, when its return was looked for, there was found but an enormous train of meteors.[13]

The career of Biela's comet is now very generally assumed to be common to every cometary body, and whenever there are seen numerous shooting stars darting rocketlike across our sky, it is thought that our earth, in its journey through space, is crossing the trail of one of these seemingly erratic bodies. The meteoric iron which fell at Mazapil, Mexico, on November 27, 1885, is considered by some as a fragment of the Biela comet.

Seemingly this should be conclusive, but it is not. It appears that the velocity with which *some* meteorites penetrate our atmosphere is too great to allow of their being considered as belonging to our solar system, as do the comets. They are interstellar rather than interplanetary. The Italian astronomer, Schiaparelli, was inclined on this account to regard the large meteorites as coming from sources outside of our system, and Olivier writes: "We have positive proof that many meteorites come from interstellar space, while all comets seem to belong to our system." So far as I am aware, but one writer—Pickering—has ventured the suggestion—and it is but a venture—that there may be a difference in kind in the meteorites from near and distant sources.[14]

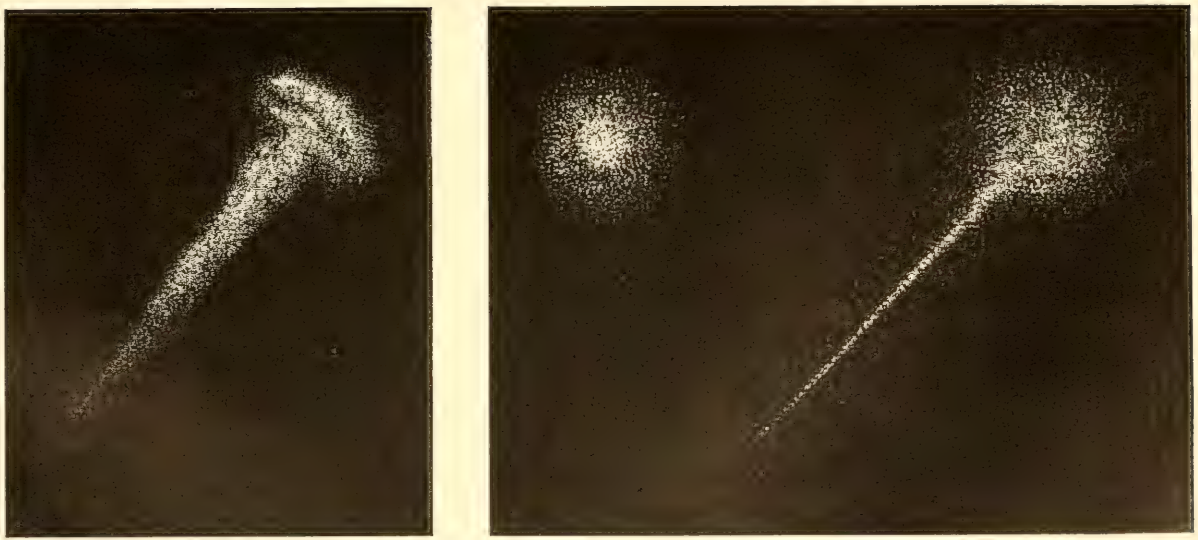
Do meteorites of like nature have a common origin? The

[13] Five or more well-known comets have completely disappeared, and the meteors in each group are distributed along the orbit of their maternal ancestor.

[14] The theory of Professor Stroemgren of Denmark, as noted in *Science News* (*Science*, January 19, 1923) maintains:

"That all comets originally traveled in elliptical or closed orbits, periodically coming closer to the sun from the outer regions of the planetary system. It maintains that the material composing comets is a part of the original nebula out of which the sun and his family are thought to have formed. According to this theory, the disturbing influences of the planets have changed the orbits of some comets from the closed-path to the open form. That is, the perturbations by the planets have resulted in throwing some of the original material of the solar system off of its beaten track and out into the emptiness of interstellar space, never to return."

PLATE 31



Biela's comet before and after division. (From *Knowledge*, Dec. 16, 1881)

most systematic investigations made of late years with reference to the possible identity of source of meteorites of like chemical and mineralogical nature are those of A. G. Högbom,[15] of Upsala, and F. Berwerth, of Vienna. Through means of a graphic chart upon which he has tabulated all known falls according to the day, month, and year, and differentiated the kinds each by a special symbol, the first-named has shown that the meteorites have a somewhat irregular distribution, so that a single day or group of days may show many falls, while on intervening days there are none. The question arose if this irregularity could be explained on the ground that the falls belonging to the same or closely neighboring days of successive years may come from the same source—may originate from a swarm of meteors which many times but at regular periods has crossed the earth's path. The suggestion is particularly pertinent when the kind of meteorite is considered. Thus it is shown that of the group of howardites, of which but nine falls were then known, three fell during the first weeks of August, and three others in the first half of December. With the December howardites there occur a bustite, a chladnite, and a howarditic chrondrite, all closely related forms. Around the first of October is shown a chassignite, two howarditic chrondrites, and a howardite. A like association occurs also at the end of March. Still another type, that of the eukrites, was at time of writing represented by three falls the dates of which were known, two of which occurred in June, the 13th and 15th respectively; the third on May 22. A fourth fell on June 28, 1911.

Recent falls do not, however, in all cases support these apparent conclusions, as is shown in the following table which includes two additional falls of howardites since the appearance of Professor Högbom's paper. As a matter of additional interest, the original weights, so far as known, and that of each now preserved, are also given.

[15] *Bull. Geol. Inst. Univ. Upsala*, Vol. 5, 1900-1901, p. 132.

HOWARDITES

Locality of Fall	Date of Fall	Original Wt.	Known Wt.
Massing, Germany.....	Dec. 13, 1803	1.6 kg.	74 gr.
Loutolax, Finland......	Dec. 13, 1813	?	894 gr.
Nobleboro, U. S. A.....	Aug. 7, 1823	1.80–2.75 kg.	78 gr.
Bialystok, Poland......	Oct. 5, 1827	4.0 kg.	627 gr.
La Vivionerre, France..	July 14, 1845	780 gr.	799 gr.
Petersburg, U. S. A....	Aug. 5, 1855	1764 gr.	399 gr.
Zmenj, Russia.........	Aug. ?, 1858	246 gr.	155 gr.
Frankfort, U. S. A.....	Dec. 5, 1868	650 gr.	535 gr.
Yodze, Russia.........	June 17, 1877	?	43 gr.
Pawlovka, Russia......	Aug. 2, 1882	2.0 kg.	1123 gr.
Bholghati, India.......	Oct. 29, 1905	2.0 kg.	1028 gr.
Simondium, S. Africa...	?	?	1000 gr.

Disregarding Simondium, but including Zmenj, of which the day of the month is unknown, it appears that one has fallen in June, one in July, four in August, two in October, and three in December.

The group of chladnites would, on account of their distinctive character, seem favorable to calculations of this nature, but these, too, fail to yield definite results, as seen below.

CHLADNITES

Name	Date of Fall
Manegaon, India..............................	June 29, 1843
Bishopville, U. S. A..........................	Mar. 29, 1843
Shalka, India................................	Nov. 30, 1850
Ibbenbuhren, Germany.........................	June 17, 1870
Cumberland Falls, U. S. A.....................	Apr. 9, 1919
Johnstown, U. S. A...........................	July 5, 1924

Berwerth[16] followed out the same line of thought, utilizing the same data but grouping them in a slightly

[16] *Sitz. der Kais. Akad. der Wiss.*, Bd. cxvi, Abt. ii, 1907.

different manner, and reached conclusions quite similar to those of Högbom. He regards the meteoric streams as originating through the throwing off of particles from some of the smaller heavenly bodies, each such stream possessing its own degree of homogeneity but differing from that of another stream. When there is an intersection of the orbits of the earth and these streams, each may leave its own characteristic record of meteoric matter. He finds, for instance, as did Högbom and Tschermak, the stones of the class of eukrites offering the most conclusive evidence of such conditions. The same reservations apply in this case as in that above. Here, as in many another theory, more observations are needed before conclusions can be reached.[17]

In this connection the following table compiled by Dr. Peter Tscherwinsky[18] is of interest. It shows the total number of observed falls, grouped by months.

January....	30	May.......	50	September..	34
February...	26	June.......	51	October....	29
March.....	22	July.......	40	November..	30
April......	43	August.....	40	December..	27
				Total....	422

From this it is readily apparent that the greatest number of actually observed falls occur in May and June, a fact which does not accord with the idea that their source is that of the periodic showers.

As having a possible bearing upon the subject, the following calculations were made by Merrill,[19] showing the percentage number of falls and finds with reference to their varying basicity:

Of the total 367 known meteoric irons there were seen to

[17] It may be added that Professor Haskins, of Chicago, has recently compared the chlorine of meteorites with that of terrestrial minerals, with reference to its isotopes and atomic weights, and finds them identical. He regards this as indicative of a common origin—the sun—for the two bodies.

[18] *Centralblatt fur Min., Geol., etc.*, No. 7, 1926, p. 239.

[19] *Proc. Nat. Acad. Sci.*, Vol. 5, 1919, pp. 37–39.

fall but seventeen, or less than five per cent. These are essentially metallic; ultra basic.

Of the thirty-one known stony irons variously classed as lodranites, pallasites, and mesosiderites, carrying at times as high as fifty per cent metal, there were seen to fall but five, or, in round numbers, sixteen per cent.

Of the 370 known stones composed mainly of silicate minerals, with chondritic structure, carrying from five to twenty-five per cent metal (howarditic chondrites to ureilites inclusive), there were seen to fall 322, or eighty-seven per cent.

Of the twenty-one calcium-aluminum-rich stones, carrying less than one per cent metal, free of chondrules, and variously classed as angrites, eukrites, shergottites, and howardites, there were seen to fall twenty, or ninety-five per cent.

Of the twelve magnesia-rich stones essentially free from metal, without chondrules, and classed as bustites, chassignites, chladnites, and amphoterites, the most acidic types known, there were seen to fall twelve, or one hundred per cent.

The suggestion is made, though not emphasized, that there is indicated a gradually increasing acidity of the incoming material as time goes on, and reference also made to the possibility that meteors of present-day showers may be of an easily combustible nature, and hence consumed before reaching the earth.

It has been shown that the number of meteors observed between the hours of midnight and 6 a.m. was larger than for any corresponding period of the day. That there is a discrepancy between this record and that of actual falls was pointed out in 1861 by Haidinger whose record of 126 observed falls shows a slight excess in the number falling in the afternoon, the hours from noon to 9 p. m. being particularly prolific. O. C. Farrington has recently made a new compilation from data now available and shows that out of 273 falls, the records of which are fairly satisfactory, 184 occurred between noon and midnight and but eighty-nine between midnight and noon. Such a discrepancy may be accounted for in part by the possible difference in quantity and kind of material, and in part by the direction of travel and the consequent heat generated in passage.

In the following table is given the number of annually recorded falls, the authenticity of which has been placed beyond question through the finding and preservation of at least a portion of the material. That the numbers given are below those of the actual falls is almost self-evident, many not having been seen, and many that were seen not recorded.

ANNUAL FALLS OF METEORITES SINCE 1880

Year	No.	Year	No.
1880	3	1903	6
1881	2	1904	3
1882	4	1905	4
1883	3	1906	2
1884	3	1907	3
1885	4	1908	3
1886	7	1909	3
1887	6	1910	7
1888	0	1911	3
1889	5	1912	3
1890	6	1913	1
1891	2	1914	3
1892	3	1915	2
1893	4	1916	5
1894	3	1917	5
1895	3	1918	2
1896	4	1919	2
1897	6	1920	3
1898	3	1921	6
1899	5	1922	1
1900	4	1923	2
1901	3	1924	2
1902	6	1925	

We cannot do better in closing this review than to quote the summary given by Professor Olivier in his work, *Meteors*, elsewhere referred to:

1. There is no difference except mass and geocentric velocity between meteorites, fireballs, and meteors.

2. Representatives of all these three classes of bodies seem intimately connected with comets in our solar system. And possible connections between small asteroids, satellites, and comets' nuclei are appearing, in view of recent observations.

3. Large numbers of meteorites, fireballs, and meteors also come to us from outer space. This infers conditions in numerous stellar systems enough similar to our own to generate similar bodies.

The problem of source will probably only be solved through the accumulation of evidence bearing upon the apparent orbits. This, owing to the very brief period of observation and the unexpectedness of the phenomena and hence unpreparedness on the part of the competent observer, must be a matter of extreme slowness. We must be prepared to wait.

Dr. E. A. Wülfing, of Heidelberg, has issued for the guidance of observers a series of twenty questions concerning which information is desired, of which the following is a condensed translation:

A. Appearance of the meteor in the heavens.

1. At what time (day, hour, and minute) did the meteor appear?
2. How brilliant and how large was its appearance in comparison with celestial bodies or objects, whether like a star of the 5th, 4th, 3rd, 2nd, or 1st magnitude, or compared with Jupiter, Venus, or the moon?
3. What was the form, appearance, nature (shape) of the flash in various parts of the meteor's course—scintillating, flashing, diffused, explosive? (Sketch.)
4. What was its color?
5. How long did the light last in its entirety and in single portions of the course? Could variations in speed of the meteor be noted? Did it travel first rapidly, then move slowly, and finally come to a stop?

6. Did the meteor show a trail and leave a glowing train or smoke cloud?
7. How long did this remain visible?
8. What form did the smoke cloud assume with lapse of time?
9. What color did it have?
10. What position did the course of the meteor take in space, with reference to other celestial or terrestrial bodies?

B. Sound phenomena.

11. How much time elapsed after the first flash of the meteor before any sound was heard?
12. How long did the various noises last, and what were their characteristics?
13. Did many sounds, as crackling and hissing come very soon, *i.e.*, within a second after the flash, to the ear of the observer?

C. Observations on the fallen meteorite.

14. How much time elapsed after the fall before the meteorite was touched, or taken up?
15. Note the position of the observer and the distribution, according to size and weight, of the individual meteorites comprised in a single fall?
16. What was the nature of the soil? Were trees, shrubbery, or buildings affected?
17. How deeply did the meteorite, or any pieces of the same bury themselves in the ground? Did any lie on the immediate surface, or bound up from the ground?
18. What was the form and depth of the depression made by the meteorite, and was the earth compacted beneath it?
19. Was the meteorite hot or cold? Did the compressed material show signs of heat? Did the meteorite smoke, or give off any odor?
20. Did the meteorite strike the ground before or after the various sound phenomena?

It is of course not expected that any one individual will be able to answer all of the above. Fragmentary evidence is, however, of value if carefully recorded and placed in proper hands, such as any astronomical observatory or scientific institution where meteorites are being studied.

CHAPTER VIII

EARLY USES OF METEORIC IRON

It would seem but natural that a material like an iron meteorite, consisting largely of metal, should early have been put to some industrial use, and particularly before the discovery of processes for smelting metals from their ores. There is, however, in the whole course of history nothing, with a few quite unimportant exceptions, to show that meteorites were regarded as other than objects of veneration or curiosity. This, in some instances, as that of Canyon Diablo, seems really extraordinary, since this iron occurs locally in small, often sharply edged flakes scattered over a nearly verdureless plain where are today abundant signs of Indian occupancy. Yet there has to be recorded a single instance indicative that it was made use of or otherwise noticed by them.

One of the earliest authentic accounts bearing upon the subject which I find, is from the English *Philosophical Magazine* for 1803, and refers to a meteoric iron which fell in the pargana of Jalindher, Lahore, India, in 1620. Omitting sundry seemingly improbable details relative to the fall, the writer says:

> I committed it [the meteoric iron] to a skilful artisan with orders to make of it a sabre, a knife, and a dagger. The workman [soon] reported that the substance was not malleable, *but shivered into pieces under the hammer.*
>
> Upon this I ordered it to be mixed with other iron. Conformably to my orders three parts of the iron of lightning were mixed with one part of common iron; and from the mixture were made two sabres, one knife, and one dagger.
>
> By the addition of the common iron, the [new] substance acquired a fine temper; the blade proving as elastic as the most genuine blade

of Ulmanny and of the south, and bending like them without leaving any mark of the bend. I had them tried in my presence, and found them cut excellently; as well [indeed] as the best genuine sabres. One of these sabres I named *katai*, or the *cutter;* and the other, *burk-serisht*, or the *lightning-natured.*

In 1805, Mr. James Sowerby received from South Africa a piece of meteoric iron from which was forged a sword, which he presented to the Emperor of Russia with the following letter:[1]

May it please your Majesty:

The meteoric iron of which this blade has been hammered, was found about 200 miles within the Cape of Good Hope by Captain Barrow. It has been examined by my countryman Smithson Tennant, Esq., who established its nature by discovering about 10 per cent of nickel in it. It is the only sword ever made of that rare and extraordinary metal. That your Majesty may be graciously pleased to honor an humble individual by receiving it, is the ambitious hope of

Your Majesty's most obedient
and ever grateful servant,
Jas. Sowerby.

July 3, 1814.

The blade of this sword, we are informed, was hammered out at a red heat, but of a single piece without admixture of foreign material.

Its spring was given it by hammering when cold. The haft was lengthened by welding on a small piece of steel, it was found to work very pleasantly, the whole operation taking about 10 hours. The mounting and engraving occupied the two following days. Thus no sword was ever completed from the crude metal in so short a space of time. . . . The length of the sword is two feet; it is slightly curved, pointed and sharpened at both edges to eight inches from the point; its width is 1 inch and 3/8th. The surface is not quite free from blemish, in consequence of the spreading of some minute flaws in the material. . . . It possesses an excellent spring, much hardness, considering it is not steel, etc.

Fletcher, in his description of the Nejed, Arabia, meteorite,[2] mentions the sending of one of these irons by

[1] *Tilloch's Magazine*, Vol. 55, 1820, pp. 49–52.

[2] *Min. Mag.*, Vol. 7, 1886–87, p. 180.

the Hajee Ahmed Khane Sarteep, of Persia, to London to be made into weapons. With what success it is not definitely known, but H. A. Ward, the veteran collector, claims[3] to have purchased from Gregory of London the identical meteorite intact, leaving the natural and indeed only inference that the weapons returned to the Hajee were of artificial metal. Be this as it may, the date (1863) is too recent to make the matter of interest from the present standpoint.

F. Berwerth, writing in Tschermak's *Mittheilungen*,[4] states that five knives, or *krises* were made for the Austrian emperor from metal cut from the iron found in 1707 at Prambanan, Java, four months being devoted to the task. The amount of material necessary for the work was obtained by heating the large mass in a forge until it was sufficiently soft to be cut with hammer and chisel. He also states that knives of meteoric iron which render their wearers invulnerable are known in Arabia.

Dr. J. Gröneman states[5] that the Javanese krises are sometimes interwelded with meteoric iron, but he adds "Unser Empu (smiths) verwendet jetzt kein meteoreisen mehr" the nickel in the modern krises being imported from Germany.

The late Admiral Peary states in his book *Northward over the Great Ice*, that the mass of meteoric iron known as "The Woman" brought by him from Greenland has been reduced by successive chipping throughout many years fully one-half or one-third its bulk, the chips so obtained being used in making arrowheads, knives, and other rough cutting tools. It seems most probable that the implements with cutting edge made from meteoric irons found by the Danish Explorer Steenstrup in the Eskimo kitchen middens were from these same sources. The celebrated Tucson, or Ring meteorite was, when

[3] *Science*, Vol. 15, 1902, p. 150.

[4] Vol. 26, 1907, p. 506.

[5] *Internat. Arch. fur Ethnographie*, Vol. 19, 1909.

found, "set up on end and used as a kind of public anvil" by the natives, a practice not uncommon with other Mexican irons. The Chattooga, Georgia, Guilford, North Carolina, and Hollands Store irons were in part worked up by a local blacksmith into nails and horseshoes. Attempts at working the well-known Bitburg, Prussia, iron, on the other hand, resulted in failure.

At the sixth annual meeting of the Association of American Geologists, in 1845, Prof. C. U. Shepard described some metal-pointed spears, examples of which had been sent him, together with information relating thereto, by Lieut. H. C. Flagg, who had obtained them from natives of St. Augustine's Bay on the southwest coast of Madagascar. The metal had a specific gravity of 7.81 and contained iron, 96.66 per cent, and nickel, with traces of cobalt, 3.34 per cent. Shepard was, therefore, inclined to believe the material meteoric. So far as could be learned, it occurred in a native state in large masses but in a region which was at that time inaccessible to the party under Lieutenant Flagg's command. There are apparently two elements of doubt as to the meteoric nature of the material, however; first, its low per cent of nickel, and second, the number and large size of the masses described by the natives, some of them being stated to be sixteen feet in diameter. If meteoric, the locality would evidently outrival that of Canyon Diablo, and in sizes, those of both Greenland and Bacubirito.[6]

There are in the National Museum collection two fine blades, one fourteen inches in length from the Nejed iron, and one seven inches in length from the Coahuila iron, forged under the direction of the present writer by the local blacksmith. Both irons worked fairly well under the hammer, but neither could be tempered to a degree to give them more than very ordinary cutting power and little elasticity. Further tests showed that the Canyon

[6] Cohen examined a fragment of this iron in the Vienna Museum and pronounced it artificial. *Ann. k.k. Nat. Hof-museum*, Bd. 13, Heft 1, 1898, p. 57.

Diablo, Casas Grandes, Mt. Joy, New Baltimore, and other irons were all malleable even when cold, and when heated to redness could be beaten down to a knife-edge without cracking. The Toluca and Williamstown irons proved more refractory. It should be noted that, for these tests, clear, homogeneous portions were taken, free as possible from all evident enclosures of schreibersite or other minerals. None of the samples tested acquired any appreciable increase in hardness when subjected to the ordinary process of tempering steel. This fact militates strongly against the reported use in the manufacture of Damascan blades. There would appear no reason, however, for the malleable irons not having been utilized, so far as quality of material is concerned, though the ordinary shape of a meteoric mass is not such as to tempt one working only with implements of stone. But, as is elsewhere noted, that they were thus utilized is by no means proven, and seems quite unlikely. All assertions favorable to the idea, when critically examined, will be found based upon assumptions and "probabilities" that are not borne out by fact. They are but manifestations on the part of certain writers to make an actuality of a preconceived possibility.

The views here expressed accord with those of W. Gowland in his lectures on *The Metals of Antiquity* (1912); St. John and Day in *Prehistoric Use of Iron and Steel;* and Dr. L. Beck in *Geseicht der Eisen.*

It may be added that artificial iron was produced by the Hittites, according to Brested,[7] as early as the thirteenth century B.C., and was in common use among the Greeks as early as 1000 B.C.

In the prehistoric earthworks forming the Turner Group of Hamilton County, Ohio, there were found a few artifacts of meteoric iron. These included hollow beads and fragments of what may have been head plates, together with several small nuggets of unworked or but

[7] Ancient Science, a History of the Early World.

The celebrated Tucson, Arizona, meteoric iron. Height 97 centimeters, width 124 centimeters; weight 621,531 grams or about 1370 lbs.

This iron, otherwise known as the Signet, or Irwin-Ainsa meteorite was brought to the Smithsonian Institution in 1863 through the influence of Dr. B. J. D. Irwin, U. S. A. The original source of the iron is believed to have been the pass of Muchachos, in the Sierra de la Madera, whence it was brought by Spanish soldiers to the old Presidio where it remained until the withdrawal of the Spanish garrison. It was then taken to Tucson and set up as a "kind of public anvil for the use of the inhabitants." The mass was sent in 1860, from Tucson to Hermosillo, and later to Guaymas by the agency of Mr. Augustin Ainsa; in 1863 it was taken to San Francisco by J. M. Ainsa, and thence by Santiago Ainsa to Washington by way of the Isthmus of Panama. The iron as a whole consists of some 93.81 per cent nickeliferous iron, 5.06 per cent of olivine, and 1.25 per cent of chromic iron and schreibersite

slightly hammered metal.[8] A mass of meteoric material weighing 767.5 grams, taken from another of the mounds, contained included olivines, suggesting its probable identity with the pallasite of Kiowa County, Kansas. From the mounds of the Hopewell Group were found small cutting implements of iron made in the form of beaver teeth. Several ear ornaments and an adz blade of the same material were found in the mounds of the Liberty Group.

In the literature are to be found numerous citations bearing upon the early use of meteoric iron, but when traced back to their original sources, these are found to be based on mere assumption or on the few cases above referred to. There is, however, no question, but that the material from several American irons was worked into horseshoe nails to an inconsequential extent by country blacksmiths. This seems to have been done more out of curiosity than through actual need of material. A recent writer,[9] it is true, would extend the record to prehistoric times, but a careful reading of his paper shows that many of his citations are mere "probabilities" and have no basis of fact, though Rickard[10] seems to have accepted them without verification. The reference by the first-mentioned to the philosopher Averroës and the meteorite of Cordova is scarcely a happy one since the meteorite is referred to as a stone and, according to the reference in the *Annalen*,[11] Averroës was mistaken as to locality.

Neumayer, in his *Erdegeschichte* also mentions the early use of meteoric iron but gives no references, and the impression is gained that he is simply repeating unverified statements from other sources, an example followed by Miller.[12]

[8] The Turner Group of Earthworks, etc., *Papers Peabody Mus. Amer. Arch. and Eth., Harvard Uni.*, Vol. 8, No. 3, 1922.

[9] Zimmer. Use of iron by primitive man. *Journ. Iron & Steel Inst.*, 1916.

[10] *Eng. & Min. Journal-Press*, May 10, 1924, p. 700.

[11] Gilbert's *Annalen*, Vol. 18, 1804, p. 305.

[12] *Sci. Monthly*, Nov. 1923, p. 438.

FINALE

So ends the story. If to the reader the conclusions drawn or the information given seem disappointingly inconclusive let him turn back for but a moment to a consideration of the facts as they first presented themselves and upon which such conclusions are based.

In the early dusk of a winter's eve some years ago the writer was walking up the gentle incline of a New England city street, walled in on either hand by houses and a few trees. Suddenly, far up toward the end of the street, but low down in the horizon there appeared, seemingly from immediately behind one of the houses, a glaring ball of light which like an immense rocket (see frontispiece) passed across his field of vision and silently disappeared. It came and went in time scarce recorded by the ticking of a watch and left but a glow on the clouds and the wavy band of the phosphorized nitrogen such as is figured on page 32. There was no explosion, no falling to the earth of solid matter as described in many similar instances. Now will the reader tell me what there was in this momentary phenomenon on which to base conclusions as to what it was, its source, or significance as a natural occurrence? He will promptly answer, "Nothing." Yet it is upon the careful recording of all such phenomena—neglecting not the slightest detail of direction, speed, light, or character of the fallen body, if such there should be, that is based all that has been given in the previous pages. The summation is for today; tomorrow we may know more.

There is occasions and causes why and wherefore in all things. —*King Henry V*, Act 5.

It remains for us to find them.

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APPENDIX I

Classification of Meteorites

I. METEORIC STONES: AEROLITES

A. Meteorites rich in calcium- and aluminum-bearing minerals, poor in nickel-iron, and without chondrules.

Andrite. Consisting essentially of a calcium-rich augite with a little olivine and iron sulphide; structure crystalline granular.

Eukrite. Consisting essentially of augite and anorthite with a little sulphide of iron; structure basaltic.

Shergottite. Consisting essentially of augite and maskelynite with a little magnesia; structure crystalline granular.

Howardite. Consisting essentially of augite, anorthite, bronzite, and olivine; structure in part tuff-like and in part crystalline.

B. Meteorites rich in magnesian minerals, poor in nickel-iron, and for the most part without chondrules.

Bustite. Consisting essentially of diopside and bronzite with some plagioclase, nickel-iron, osbornite, and oldhamite; structure crystalline.

Chassignite. Consisting essentially of olivine and a little chromite; structure crystalline granular.

Chladnite. Consisting essentially of a rhombic pyroxene; structure crystalline granular.

Amphoterite. Consisting essentially of olivine and bronzite with a little iron sulphide and nickel-iron; structure sometimes granular, sometimes chondritic.

C. Meteorites rich in magnesian minerals and consisting essentially of olivine, bronzite, nickel-iron, and iron sulphide, with a fragmental or tufflike base and chondritic structure.

Howarditic Chondrites. A group intermediate between the chondrites and achondrites.

White Chondrites. Consisting of a yellowish white tufaceous base with chondrules mostly of the same color. This group is divided into three subgroups: (a) White chondrites (Cw); (b) veined white chondrites (Cwa); and (c) breccia-like white chondrites (Cwb).

Intermediate Chondrites. A group including forms intermediate between the white and the gray chondrites. This group is divided also into three subgroups: (a) Intermediate chondrites (Ci); (b) veined intermediate chondrites (Cia); and (c) breccia-like intermediate chondrites (Cib).

Gray Chondrites. Consisting of a yellowish to bluish gray tufflike base, with variously colored chondrules which are firmly imbedded in the groundmass. The group is divided into: (a) Gray chondrites (Cg); (b) veined gray chondrites (Cga); and (c) breccia-like gray chondrites (Cgb).

Black Chondrites. Consisting of a dark-gray to black firm chondritic mass, the color of which is due in part to carbon and in part to iron sulphide; chondrules mostly of a light color.

Spherulitic (Kugelchen) Chondrites. Consisting of numerous hard and well-formed chondrules in every varying proportion, in a tufflike or crystalline ground, sometimes so loosely imbedded as to break away from the ground and sometimes breaking with it. This group is divided into five subgroups as follows: (a) Ornansite and ngawite (Cco and Ccu); (b) spherical or Kugelchen chondrites (Cc); (c) veined Kugelchen chondrites (Cca); (d) breccia-like Kugelchen chondrites (Ccb); (e) crystalline Kugelchen chondrites (Cck).

CRSYTALLINE CHONDRITES. Consisting of a crystalline groundmass with firmly imbedded chondrules. The group is divided into three subgroups: (a) Crystalline chondrites (Ck); (b) veined crystalline chondrites (Cka); (c) breccia-like crystalline chondrites (Ckb).

CARBONACEOUS CHONDRITES (K AND Kc). This includes a group of chondritic stones impregnated with carbon and containing little or no iron.

ORVINITE. A small group consisting of chondrules in a blackish ground, showing a fluidal structure. It has at present but one representative.

TADJERITE. Consisting of a dark, for the most part half glassy ground containing chondrules; without recognizable crust.

URELITE. Consisting essentially of olivine, sometimes chondritic and sometimes granular structure, of a dark, nearly black color, and often showing transition stages into the next class.

II. STONY IRON METEORITES: SIDEROLITES

Meteorites consisting of silicate minerals in a more or less disconnected mesh or sponge of nickel-iron.

LODRANITE. Consisting of a crystalline granular mixture of olivine and bronzite in a fine, more or less disconnected network or sponge of metal.

MESOSIDERITE (GRAHAMITE). Consisting essentially of olivine, bronzite, plagioclase, and augite, sometimes chondritic, sometimes crystalline granular, in a more or less interrupted network or sponge of metal.

SIDEROPHYR. Consisting essentially of bronzite and nickel-iron with accessory asmanite in a network of nickel-iron of octahedral crystallization and showing Widmanstätten figures.

PALLASITE. Consisting of olivine in a continuous network or sponge of metal.

METEORIC-IRON BRECCIA. Meteorites consisting of crystalline chondrules in a breccia-like mass of octahedral iron.

METEORIC IRON OF NETSCHAËVO. Meteorites consisting of crystalline chondrules in a mass of octahedral nickel-iron.

III. NICKEL-IRON METEORITES: SIDERITES

Meteorites consisting essentially of nickel-iron with iron sulphide and phosphide, and usually graphite or other form of carbon.

OCTAHEDRAL IRONS. Consisting essentially of nickel-iron alloys arranged in the form of plates parallel to the faces of an octahedron, and often interlaminated with thin plates of schreibersite. On etching with acid they show Widmanstätten figures. According to the thickness of the plates they are divided as follows: (a) Octahedral irons with lamellae some 0.1 mm. in thickness (Off); (b) octahedral irons with lamellae 0.15 to 0.4 mm. in thickness (Of); (c) octahedral irons with lamellae 0.5 to 1.0 mm. in thickness (Om); (d) octahedral irons with lamellae 1.5 to 2.0 mm. in thickness (Og); (e) octahedral irons with lamellae over 2.5 mm. in thickness (Ogg); (f) breccialike octahedral irons (Obz).

HEXAHEDRAL IRONS. Homogeneous masses of nickel-iron with evident cleavage parallel to the faces of a hexahedron and showing lamellae due to the twinning of a cube on an octahedral face. On etching they show Neumann lines. These are divided into: (a) Hexahedral irons (H); (b) brecciated hexahedral irons (Hb); (c) the Cape Iron group (Hca); (d) the Chesterville group (Hch).

MASSIVE IRONS. Amorphous irons showing neither Neumann nor Widmanstätten lines, nor other structural features such as permit satisfactory classification. Doctor Brezina has divided them into five groups: (a) The Babb's Mill group (Db); (b) the Nedagolla group (Dn); (c) the Primitiva group (Dp); (d) the Senegal group (Ds); (e) the Tucson group (Dt).

This classification, so far as it relates to the stony meteorites, has been modified by Prior[1] as follows:

I. Chondrites which, according to increasing percentages of nickel in the nickeliferous iron and corresponding increase of ferrous oxide in the magnesian silicates, are divided into:

(a) Enstatite-chondrites.
(b) Bronzite-chondrites.
(c) Hypersthene-chondrites.

To the members of each of these groups are applied the qualifications according to color (white, intermediate, gray, black); structure (crystalline, spherical, brecciated, veined); and composition (carbonaceous, etc.), used in the Tschermak-Brezina classification.

II. Achondrites. Divided, according to the content of lime, into:

(a) Calcium-poor achondrites which are subdivided into:

1. Enstatite-achondrites, or *Aubrites*, corresponding to the enstatite-chondrites.

[1] *Min. Mag.*, Vol. 19, 1920, pp. 51-63.

2. Clinobronzite-olivine-achondrites, or *Ureilites*, corresponding to bronzite-chondrites.

3. Hypersthene - olivine achondrites, or *Amphoterites* (and *Rodites*). 4. Hypersthene-achondrites, or *Diogenites*. 5. Olivine-achondrites, or *Chassignites*.	corresponding to hypersthene chondrites.

(b) Calcium-rich achondrites, which are subdivided into:

1. Augite-achondrites, or *Angrites*.
2. Diopside-olivine-achondrites, or *Nakhlites*.
3. Clinohypersthene - anorthite - achondrites, or *Eukrites*; including *Shergottites* in which anorthite is replaced by maskelynite.
4. Hypersthene - clinohypersthene - anorthite - achondrites, or *Howardites*.

APPENDIX II

List of All Known Meteorites Seen to Fall, Portions of Which Have Been Preserved

I. STONES

Adhi Kot, Nurpur, Shahpur dist., Punjab, India.
Fell at noon on May 1, 1919.
A single stone of 4,239 grams weight.

Agen, Lot-et-Garonne, France.
Fell at noon, September 5, 1814.
A shower of stones the total weight of which was about 20 kilograms, the largest weighing about 9 kilograms.

Akbarpur, Saharanpur district, United Provinces, India.
Fell 8 a.m., April 8, 1838.
A single stone weighing about 4 pounds.

Alais, Gard, France.
Fell 5 p.m., March 15, 1806.
Two stones of about 4 and 2 kilograms weight respectively.

Albareto, Modena, Italy.
Fell 5 p.m., about the middle of July, 1766.
A single large stone weighing about 12 kilograms.

Aldsworth, Cirencester, Gloucestershire, England.
Fell 4:30 p.m., August 4, 1835.
A shower of small stones, the largest weighing about 1½ pounds.

Alexandrovsky, Nyezhin dist., Chernigov govt., Ukraine.
Fell July 8, 1900.
One stone of 9.4 kilograms weight.

ALFIANELLO, Brescia, Italy.
Fell 3 p.m., February 16, 1883.
A single stone weighing about 228 kilograms.

ALLEGAN, Allegan County, Michigan.
Fell at 8 a.m., on July 10, 1899. (See Plate 5.)
A single stone weighing about 70 pounds broken in the fall.

ALLEPPO, Syria.
Thought to have fallen about 1873.

ALLESSANDRIA, Piedmont, Italy.
Fell 11:45 a.m., February 2, 1860.
Several stones from 300 grams to one kilogram each.

ALTAI, Tomsk, Siberia.
Fell at 11:30 p.m. on May 22, 1904.
A shower of small stones of which but six were preserved.

AMBAPUR NAGLA, Aligarh district, United Provinces, India.
Fell at 1 a.m. on May 27, 1895.
A single stone which broke in two pieces in falling.

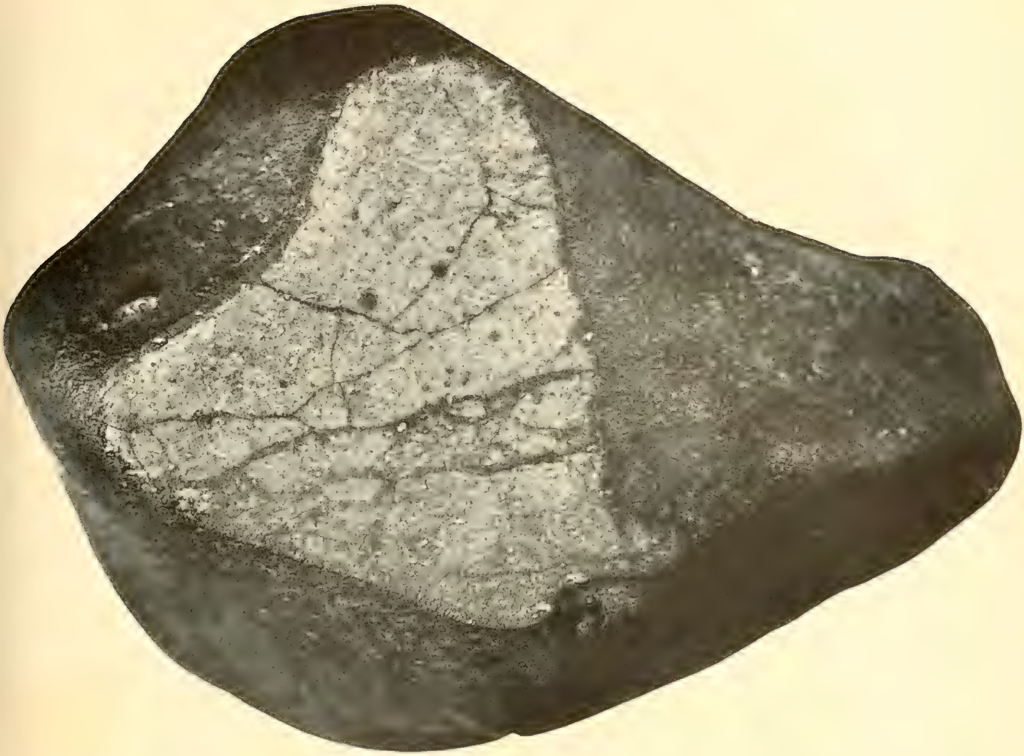
ANDHARA, Muzzaffarpur district, Bengal, India.
Fell at 4 p.m. on Dec. 2, 1880.
A single stone weighing about 6 pounds (2,727 grams). This stone was made by the natives an object of adoration, and a temple built over it. (See page 38.)

ANDOVER, Oxford County, Maine.
Fell at 7:30 a.m. on Aug. 5, 1898.
A single stone weighing about 7 pounds (3,181 grams).

ANGERS, Maine-et-Loire, France.
Fell at 8:15 p.m. on June 3, 1822.
A single stone of about 1 kilogram weight.

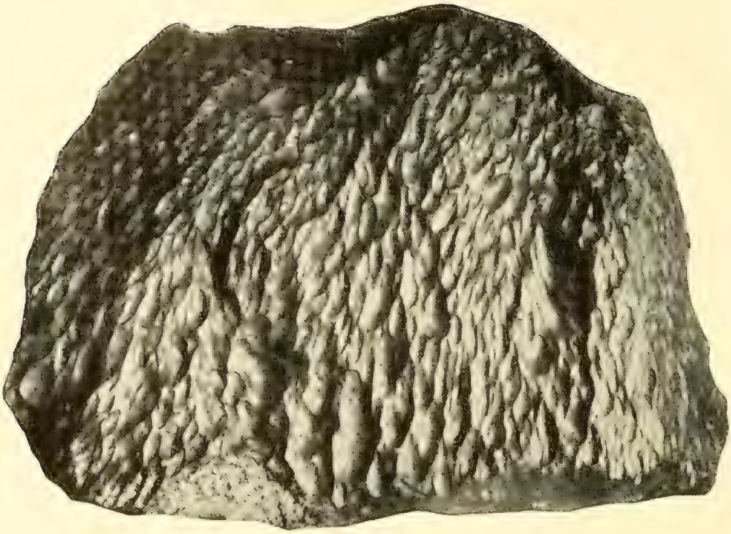
ANGRA DOS REIS, Rio de Janeiro, Brazil.
Fell at 5 a.m. on Jan. 30, 1869.
A single stone weighing about 1,200 grams.

APPLEY BRIDGE, Lancashire, England.
Fell at 8:45 a.m. on Oct. 13, 1914.
A single stone weighing about 33 pounds (15 kilograms) found the day following the appearance of a luminous meteor.



This meteoric stone, weighing 345 grams, fell Feb. 2, 1922, on the farm of Mr. Allen Cox about one and one-half miles west of Baldwyn, Mississippi. It was seen to fall by a negro tenant who was badly frightened and reported the occurrence to Mr. Cox who went with him and picked up the stone which had buried itself some three or four inches in soft clay. It was reported as still warm and giving off a smell very much like brimstone or flint when struck with a steel hammer. The attention of the colored man was first attracted by a humming noise which he mistook for an airplane. The noise increased for a moment when a rush of air was felt and the stone buried itself near his feet. He did not at any time see the stone until it hit the ground although the sound was first heard in a northwesterly direction

PLATE 34



Meteoric Stone, Bath Furnace, Kentucky.

This beautiful stone, one of three constituting the entire fall, so far as known, fell early in the evening of Nov. 15, 1902, accompanied by a glaring light and heavy detonations. Two of the three pieces were recovered within a few hours; the third shown in the figure was not found until May of 1903. The stone, which is now in the Field Museum, of Chicago, weighs 177¼ pounds or 80 kilograms and is remarkable for the beauty and perfection of its flutings which radiate from the apex in all directions

APT, Vaucluse, France.
Fell at 10:30 a.m., Oct. 8, 1803.
A single stone weighing about 3,250 grams.

ASSISSI, Perugia, Italy.
Fell at 7 a.m. on May 24, 1886.
A single stone of about 2 kilograms weight.

ATARRA, Manikpur, Banda dist., United Provinces, India.
Fell at 5:35 p.m., Dec. 23, 1920.
Three stones of 1,280 grams weight.

ATEMAJAC, Sierra de Topalpo, Jalisco, Mexico.
Fell on Feb. 2, 1896.
A small stone of which little is yet known.

AUBRES, Nyons, Drôme, France.
Fell at 3 p.m. on Sept. 14, 1836.
A single stone of some 800 grams weight.

AUMALE, Alger, Algeria.
Fell between 11 and 12 a.m. on Aug. 25, 1865.
Two stones of about 25 kilograms each.

AUMIÈRES, Lozère, France.
Fell at 9 p.m. on June 3, 1842.
A single stone of about 2 kilograms weight.

AUSSUM, Haute Garonne, France.
Fell at 7:30 a.m. on Dec. 9, 1858.
Two stones of about 9 and 41 kilograms weight.

AVILEZ, Cuencamé, Durango, Mexico.
Fell in June, 1855.
A shower of "several" stones but only a few small pieces saved.

BACHMUT, Ekaterinoslav, Ukraine.
Fell at noon on Feb. 15, 1814.
A single stone of 18 kilograms weight.

BALDWYN, Lee County, Mississippi.
Fell in the daytime, Feb. 2, 1922.
One small stone of 345 grams weight. (See Plate 33.)

BALI mission station, Cameroon, West Africa.
Fell at 11 a.m., Nov. 22 or 23, 1907.
Fall noted, but no description.

BANDONG, Java.
Fell at 1:30 p.m., Dec. 10, 1871.
Six stones fell, of a total weight of about 11,500 grams.

BANSWAL, Dehra Dun district, United Provinces, India.
Fell at 6 p.m. on Jan. 12, 1913.
A single stone fell of unknown weight, and of which but about 14 grams were saved.

BARBOTAN, Landes, France.
Fell at 9 p.m. on July 24, 1790.
A shower of stones, the largest weighing 9,000 grams.

BARNTRUP, Lippe, Germany.
Fell on May 28, 1886.
A small stone of but 17 grams.

BAROTI, Bilaspur, Simla Hill States, Punjab, India.
Fell at 10 a.m. on Sept. 15, 1910.
But one stone, of about 4,041 grams weight.

BATH, Brown County, South Dakota.
Fell at 4 p.m. on Aug. 29, 1892.
One stone of about 21,250 grams.

BATH FURNACE, Bath County, Kentucky.
Fell at 6:45 p.m. on Nov. 15, 1902.
Three stones fell, the largest, remarkable for the perfection of its flutings, weighing 80,455 grams. (See Plate 34.)

BEAVER CREEK, West Kootenay district, British Columbia.
Fell at 3:30 p.m., May 26, 1893.
A single stone weighing 14,909 grams.

BENARES, United Provinces, India.
Fell at 8 p.m., Dec. 19, 1798.
A shower of stones, one of about 2 pounds weight passing through the roof of a hut.

BEREBA, Haute Volta, French West Africa.
Fell at 3:30 p.m., June 27, 1924.
One stone of about 18 kilograms belonging to the rare group of eukrites.

Berlanguillas, Burgos, Spain.
Fell at 8 p.m. on July 8, 1811.
Three stones known to have fallen, the largest weighing about 2,500 grams.

Bethlehem, Albany County, New York.
Fell at 7:30 a.m., Aug. 11, 1859.
A single small stone the size of a pigeon's egg.

Beuste, Pau, Basse-Pyrénées, France.
Fell on an afternoon in May, 1859.
Two fragments known weighing respectively 1,500 and 500 grams.

Bherai, Junagarh, Kathiawar, Bombay, India.
Fell at 8 a.m. on April 28, 1893.
A small stone of less than one fourth of a gram.

Bholghati, Deoli pargana, Maurbhanj, Orissa, India.
Fell at 8:30 a.m. on Oct. 29, 1905.
Two stones of about 909 and 1,591 grams.

Bialystok, Grono, Poland.
Fell at 9:30 a.m., Oct. 5, 1827.
A shower of stones, of which but 4 weighing all told 4,000 grams were found.

Bielokrynitschie, Zaslavl, Volhynia, Ukraine.
Fell at 6 p.m. on Jan. 1, 1887.
A shower of which eight were found the largest weighing 2 kilograms.

Bishopville, Sumter County, South Carolina.
Fell Mar. 25, 1843.
A single stone of about 13 pounds (5,909 grams) belonging to the rare group of aubrites of which but three representatives are known.

Bishunpur, Mirzapur district, United Provinces, India.
Fell at 3 p.m. on April 26, 1895.
Four stones reported to have fallen, but only two small ones weighing 97 and 942 grams preserved.

Bjelaja Zerkov, Kiev, Ukraine.
Fell on Jan. 15, 1796.
One individual weighing 1,400 grams.

Bjurböle, Borga, Nyland, Finland.
Fell at 10:30 p.m. on Mar. 12, 1899.
Several stones of which the largest weighed 80 kilograms; the total weight of all being 330 kilograms.

Blanket, Brown County, Texas.
Fell at 10:30 p.m. on May 30, 1909.
Two stones weighing respectively 1,500 and 1,600 grams.

Blansko, Brno, Moravia, Czechoslovakia.
Fell at 6:30 p.m., Nov. 25, 1833.
A shower of stones eight of which, weighing altogether but 350 grams, were found.

Bocas, San Luis Potosi, Mexico.
Fell Nov. 24, 1804.
But small fragments and little information regarding this fall known.

Borgo San Donnino, Parma, Italy.
Fell at noon on April 19, 1808.
Several stones fell, the largest weighing about 1 kilogram.

Bori, Betul district, Central Provinces, India.
Fell at 4 p.m. on May 9, 1894.
A single stone of about 8,636 grams.

Borkut, Marmoros, Ruthenia, Czechoslovakia.
Fell at 3 p.m. on Oct. 13, 1852.
A single stone weighing about 7 kilograms.

Borodino, Moscow, Russia.
Fell at 1 a.m. on Sept. 5, 1812.
A single stone weighing about 500 grams.

Botschetschki, Kursk, Russia.
A stone of 614 grams weight said to have fallen at the end of 1823.

Bremervörde, Hanover, Germany.
Fell at 5 p.m. on May 13, 1855.
Five stones known of this fall, weighing altogether 7,250 grams, the largest 2,750 grams.

Bur-Gheluai, Bur-Hagaba district, Italian Somaliland.
Fell at 8 a.m. on Oct. 16, 1919.

A shower of over 100 stones of a total weight of about 120,000 grams, the largest 15,400 grams.

BUSCHHOF, Zemgale, Latvia.

Fell at 7:30 a.m. on June 2, 1863.

A single stone of about 5,000 grams.

BUSTEE, bet. Gorakhpur and Fyzabad, Basti district, United Provinces, India.

Fell at 10 a.m., Dec. 2, 1852.

A type of exceedingly rare meteorite weighing about 1,600 grams and containing a nodular mass from which were first described the minerals osbornite and oldhamite.

BUTSURA, Champaran district, Bihar, India.

Fell about noon on May 12, 1861.

There were five stones in this fall and although scattered at intervals of 2-3 miles apart, all could be fitted together showing that they were once portions of the same mass.

CABEZA DE MAYO, Murcia, Spain.

Fell at 6:15 a.m. on Aug. 18, 1870.

A single stone weighing some 25 kilograms.

CANELLAS, Barcelona, Spain.

Fell at 1:30 p.m. on May 14, 1861.

Several stones which were mostly lost or broken into small fragments.

CANGAS DE ONIS, Asturias, Spain.

Fell at 11 a.m. on Dec. 6, 1866.

A shower of stones of which the largest weighed about 11,000 grams.

CAPE GIRARDEAU, Cape Girardeau County, Missouri.

Fell at 3 p.m. on Aug. 14, 1846.

One stone of about 5 pounds (2,272 grams) weight.

CARATASH, Smyrna, Asia Minor.

Fell at 8 p.m., Aug. 22, 1902.

One stone as "big as a melon."

CASTALIA, Nash County, North Carolina.

Fell at 2:30 p.m., May 14, 1874.

A dozen or more stones fell over an area 3 × 10 miles, but only 3 of 800 grams, 1,000 grams and 5,500 grams preserved.

CASTINE, HANCOCK COUNTY, Maine.
Fell at 4 a.m., May 20, 1848.
A single stone of but about 3 ounces weight.

CERESETO, Casale, Piedmont, Italy.
Fell at 7:30 a.m. on July 17, 1840.
One stone of about 5,000 grams weight.

CHAIL, Allahabad, United Provinces, India.
Fell at 4:30 p.m. on Nov. 5, 1814.
Nineteen stones, some of them up to 18,181 grams, said to have fallen.

CHAINPUR, Azamgarh district, United Provinces, India.
Fell at 1:30 p.m., May 9, 1907.
Several stones of varying weights up to 12 pounds (5,458 grams).

CHANDAKAPUR, Berar, Central Provinces, India.
Fell at noon of June 6, 1838.
Three stones weighing about 8,864 grams.

CHANDPUR, Mainpuri district, United Provinces, India.
Fell April 6, 1885.
A single stone of about 2½ pounds was heard to fall and was found next day.

CHANGANOREIN, Cochin State, India.
Fell at 12:45 p.m., July 3, 1918.
Seven small stones, the largest, a fragment, weighing 713 grams.

CHANTONNAY, Vendée, France.
Fell at 2 a.m., Aug. 5, 1812.
A stone of 31½ kilograms fell.

CHARSONVILLE, Meung, Loiret, France.
Fell at 1:30 p.m., Nov. 23, 1810.
Three stones of 9 to 18 kilograms.

CHARWALLAS, Hissar district, Punjab, India.
Fell at 8 a.m. on June 12, 1834.

A single stone weighing 12,045 grams, which has now been almost completely lost.

CHASSIGNY, Haute Marne, France.
Fell at 8 a.m. on Oct. 3, 1815.
Four kilograms of fragments.

CHATEAU RENARD, Montargis, Loiret, France.
Fell at 1:30 p.m., June 12, 1841.
A single stone of some 30 pounds (1,364 grams) weight.

CHERVETTAZ, Palézieux, Vaud, Switzerland.
Fell at 2 p.m. on Nov. 30, 1901.
One stone of about 750 grams weight.

CLOHARS, Fouesnant, Quimper, Finistère, France.
Fell on June 21, 1822.
But six grams of the material known.

COLBY, Clark County, Wisconsin.
Fell at 6:20 p.m. on July 21, 1917.
Two stones weighing respectively 80 and 150 pounds fell and broke into pieces.

COLD BOKKEVELD, Cape Province, South Africa.
Fell at 9 a.m. on Oct. 13, 1838.
Many stones fell, the largest of about 2 kilograms weight.

COLLESCIPOLI, Terni, Umbria, Italy.
Fell at 1:30 p.m., Feb. 3, 1890.
A single stone of about 5 kilograms.

CONSTANTIA, near Cape Town, South Africa.
Fell at 4:30 p.m., Nov. 4 (?) 1906.
A single stone of about 2 pounds weight fell through the roof of a house.

COSINA, Dolores Hidalgo, Guanajuato, Mexico.
Fell at 11 a.m. in Jan., 1844.
One stone of about 1,200 grams.

CRANGANORE, Cochin State, Madras, India.
Fell 12:45 p.m., July 3, 1917.
Six stones fell of weight upwards of 1,460 grams.

CRONSTAD, Orange Free State, South Africa.
Fell at 4 p.m. on Nov. 19, 1877.

A shower of stones, the largest of which weighed about 2,727 grams.

Cross Roads, Boyett, Wilson County, North Carolina.
Fell at 5 a.m. on May 24, 1892.
One stone of but 167 grams weight.

Crumlin, County Antrim, Ireland.
Fell at 10:30 a.m. on Sept. 13, 1902.
One stone of about 9 pounds 5½ ounces.

Cumberland Falls, Whitley County, Kentucky.
Fell at noon on April 9, 1919.
Several stones, the largest estimated to have weighed some 30 pounds though it smashed in falling. A coarse brecciated stone of exceptional interest.

Cynthiana, Harrison County, Kentucky.
Fell at 4 p.m. on Jan. 23, 1877.
One stone of about 6,000 grams.

Dandapur, Gorakhpur district, United Provinces, India.
Fell at 5 p.m., Sept. 5, 1878.
Two stones of about 6½ and 5½ pounds weight.

Daniels Kuil, Griqualand West, South Africa.
Fell on March 20, 1868.
One stone of 2 pounds 5 ounces weight.

Danville, Morgan County, Alabama.
Fell at 5 p.m., Nov. 27, 1868.
Several stones fell, but one preserved, weight 4½ pounds.

Deal, Long Branch, Monmouth County, New Jersey.
Fell about 12:30 a.m., Aug. 15, 1829.
Several reported as fallen, but one small one preserved.

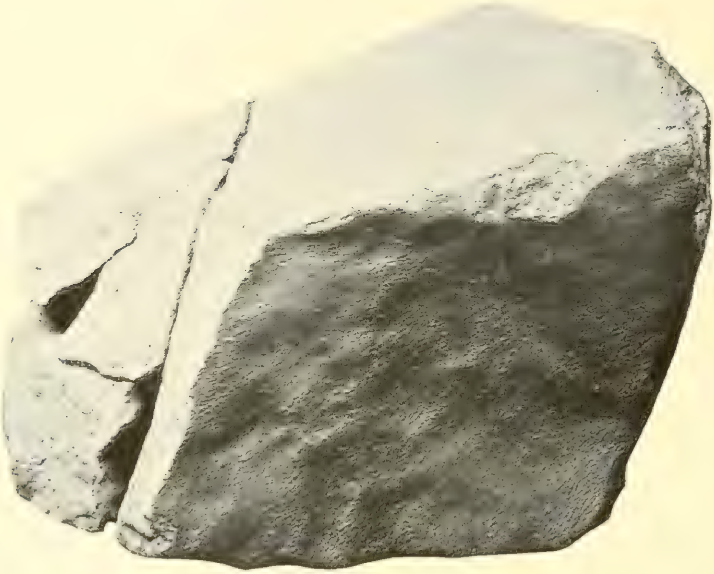
De Cewsville, Haldimand County, Ontario, Canada.
Fell at 2 p.m. on Jan. 21, 1887.
One stone only of 340 grams.

Delhi, Punjab, India.
Fell Oct. 18, 1897.
Two stones of 1 pound weight each.

Demina, Biysk dist., Altai govt., Siberia.
Fell Sept. 6, 3:30 p.m., 1911.
One or more stones of 16.4 kilograms weight.

PLATE 35

Fragment from the Ensisheim stone that fell Nov. 16, 1492. For description see p. 7



The meteoric stone that fell at Felix, Alabama, on May 15, 1900. About natural size. Weight 2,049 grams. The fall was accompanied by one very loud report followed by two lesser ones, the appearance being compared to that of a big piece of red hot iron being struck with a hammer causing many sparks to fly in all directions. Two smaller pieces fell which have become lost

DHAWAR, Bombay, India.
Fell at 1 p.m., Feb. 15, 1848.
One stone of about 4 pounds weight.
DHURMSALA, Kangra district, Punjab, India.
Fell at 2:15 p.m. on July 14, 1860.
A fall of unusual interest. Several stones, of which the largest weighed 329 pounds.
DIEP RIVER, Cape Province, South Africa.
Fell 1906.
One stone, weight not given.
DJATI-PENGILON, Ngawi district, Java.
Fell at 4:30 p.m. on Mar. 19, 1884.
A single stone of about 166 kilograms (356 pounds).
DOKACHI, Dacca district, Bengal, India.
Fell at 7 p.m. on Oct. 22, 1903.
Over 100 stones fell, of which 24 were preserved.
DOLGOVOLI, Luck, Wolyn, Poland.
Fell at 7 a.m. on June 26, 1864.
A single stone of about 1.6 kilograms.
DOMANITCH, Carakewy, Brusa, Asia Minor.
Fell Feb. 1, 1907.
Two small stones, not described.
DONGA KOHROD, Bilaspur district, Central Provinces, India.
Fell at 3 p.m. on Sept. 23, 1899.
A single stone of about 1 kilogram.
DORONINSK, Irkutsk, Siberia.
Fell at 5 p.m. on Apr. 6, 1805.
Two stones of total weight of 4.25 kilograms.
DRAKE CREEK, Nashville, Sumner County, Tennessee.
Fell at 4 p.m., May 9, 1827.
Five stones, the largest of 11½ pounds, were seen to fall.
DUNDRUM, County Tipperary, Ireland.
Fell at 7 p.m., Aug. 12, 1865.
A single stone of 4 pounds 14½ ounces weight.
DURALA, N. W. of Karnal district, Punjab, India.
Fell at noon on Feb. 18, 1815.
A single stone of about 29 pounds weight.

DURUMA, Mombasa, Wanikaland, East Africa.
Fell on Mar. 6, 1853.
A single stone of about 577 grams weight.

DYALPUR, Sultanpur district, United Provinces, India.
Fell on May 8, 1872.
A stone of but 10 ounces weight.

EICHSTÄDT, Middle Franconia, Bavaria.
Fell at 12:15 p.m. on Feb. 19, 1785.
A stone of about 3 kilograms weight.

EKH KHERA, Bisauli tahsil, Budaun district, United Provinces, India.
Fell at 2:30 a.m., April 5, 1916.
A stone of about 840 grams weight.

ELLEMEET, Isle of Schouwen, Zeeland, Holland.
Fell at 11:30 a.m., Aug. 28, 1925.
Two stones of 970 and 500 grams belonging to the rare group of rodites.

ENSISHEIM, Alsace, France.
Fell at 11:30 p.m. on Nov. 16, 1492.
A single stone of 127 kilograms weight, and of special interest for being the oldest known fall of which samples have been preserved. (See Plate 35.)

ÉPINAL, Vosges, France.
Fell at 7 a.m. on Sept. 13, 1822.
A single stone of "about the size of a 6-pound cannon ball."

ERGHEO, Brava, Italian Somaliland, E. Africa.
Fell in July, 1889.
A stone of about 20 kilograms weight.

ERXLEBEN, Magdeburg, Prussia.
Fell at 4 p.m. on April 15, 1812.
A stone of about 2.25 kilograms weight.

ESNANDES, Charente-Inférieure, France.
Fell in August, 1837.
One stone of about 1.5 kilograms weight.

ESTHERVILLE, Emmet County, Iowa.
Fell at 5 p.m. on May 10, 1879.

A shower of several large and many smaller masses, having a total weight of over 700 pounds. These meteorites belong to the class of mesosiderites and are of unusual interest, being apparently a metamorphosed agglomerate.

FARMINGTON, Washington County, Kansas.
Fell at 1 p.m. on June 25, 1890.
Two stones seen to fall, one of 188 pounds and the second of 9 pounds.

FAVARS, Aveyron, France.
Fell at 6:45 a.m. on Oct. 21, 1844.
A single stone of 15 kilograms.

FEID CHAIR, La Calle, Constantine, Algeria.
Fell at midday, August 16, 1875.
A single stone of 380 grams weight.

FELIX, Perry County, Alabama.
Fell at 11:30 a.m., May 15, 1900.
Stone of about 2 kilograms weight. (See Plate 36.)

FENG-HSIEN, northern Kiangsu, China.
Fell at 6:22 p.m., Oct. 5, 1924.
Stones fell of which but 82 grams are noted.

FERGUSON, Haywood County, North Carolina.
Fell July 18, 1889.
A single stone of about ½ pound weight.

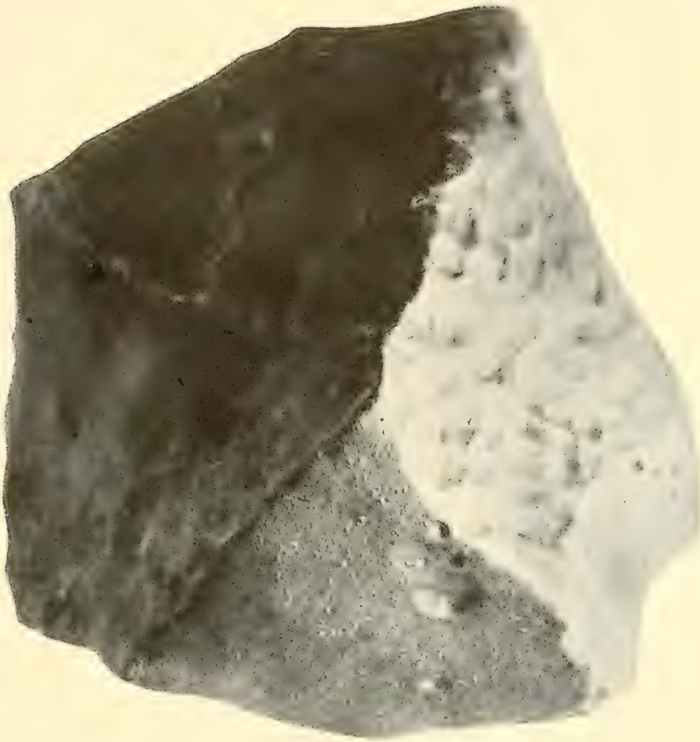
FISHER, Polk County, Minnesota.
Fell at 4 p.m. on Apr. 9, 1894.
Several stones found, the largest of which was broken up and lost, the largest remaining of about 9¼ pounds weight. (See Plate 37.)

FOREST CITY, Winnebago County, Iowa.
Fell at 5:15 p.m. on May 2, 1890.
A shower of 5 large and over 500 smaller ones of a total weight of over 125 kilograms.

FORKSVILLE, Mecklenburg County, Virginia.
Fell about 5:45 p.m., July 16, 1924.
Four stones of 853, 1,114, 1,850 and 2,250 grams weight.

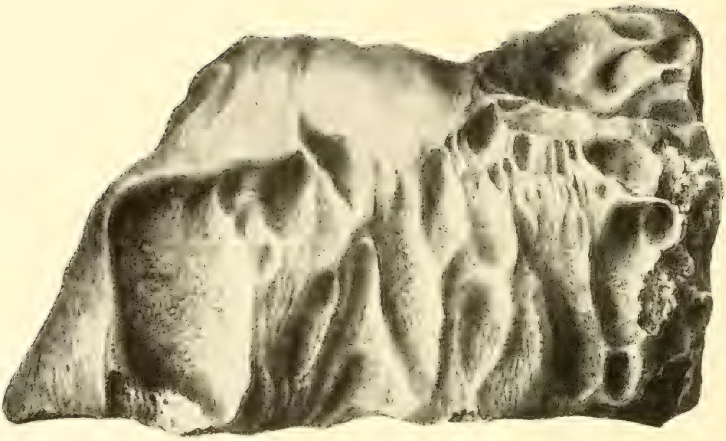
Forsbach, Hoffnungsthal, Cologne, Rhenish Prussia.
Fell at 2 p.m. on June 12, 1900.
A single stone of but 240 grams weight.
Forsyth, Monroe County, Georgia.
Fell at 3:30 p.m., May 8, 1829.
A single stone of 36 pounds weight.
Frankfort, Franklin County, Alabama.
Fell at 3 p.m., Dec. 5, 1868.
A stone of about 650 grams.
Fukutomi, Kijima, Hizen, Japan.
Fell at 1 p.m., March 19, 1882.
Two stones weighing about 9.75 kilograms.
Futtehpur, Allahabad district, United Provinces, India.
Fell at 6 p.m. on Nov. 30, 1822.
Several stones weighing from 1 to 4 pounds each.
Galapian, Agen, Lot et Garonne, France.
Fell in August (?) 1826.
One large stone said to have fallen as above.
Gambat, Khairpur State, Bombay, India.
Fell on Sept. 15, 1897.
One stone of about 14 pounds weight.
Gifu, Mino, Japan.
Fell at 5:44 a.m. on July 14, 1909.
A shower of over 100 pieces.
Girgenti, Sicily, Italy.
Fell at 1 p.m., Feb. 10, 1853.
Several stones, the largest of about 7 pounds weight.
Glasatovo, Kashin, Tver govt., Russia.
Fell at 12:45 p.m., Feb. 27, 1918.
One stone of over 150 kilograms.
Gnadenfrei, Silesia.
Fell at 4 p.m., on May 17, 1879.
Two stones of about 1,000 and 750 grams weight.
Gopalpur, Jessore district, Bengal, India.
Fell at 6 p.m. on May 23, 1865.
One stone of about 1,600 grams. (See Plate 38.)

PLATE 37



One of the fragments from the fall at Fisher, Polk County, Minnesota, April 9, 1894. Note the primary crust on the bottom and secondary on the right. Weight 4,340 grams

PLATE 38



Side view of the meteorite of Gopalpur, India, which fell on May 3, 1865. Weight 1.6 kilograms

GRAZAC, Tarn, France.
Fell at 4 a.m. on Aug. 10, 1885.
Shower of about 20 stones, the largest weighing about 600 grams.

GROSNAJA, Mekensk, Terek, Caucasus.
Fell at 7 p.m. on June 28, 1861.
A shower of which but about 3,500 grams were recovered, the rest having fallen in the River Terek.

GROSS-DIVINA, Sillein, Trencsen, Czechoslovakia.
Fell at 11:30 a.m. on July 14, 1837.
One stone of about 10½ kilograms.

GROSSLIEBENTHAL, Odessa, Ukraine.
Fell at 6:30 a.m. on Nov. 19, 1881.
One stone of about 8 kilograms weight.

GRÜNEBERG, Silesia.
Fell at 3:30 p.m. on March 22, 1841.
One stone of about 1 kilogram weight.

GUAREÑA, Badajos, Spain.
Fell at 10:30 a.m. on July 20, 1892.
Two stones weighing 25 and 7 kilograms.

GUČA, Serbia.
Fell on Sept. 28, 1891.
A single stone of unknown weight of which a fragment weighing 1,915 grams is preserved.

GUMOSCHNIK, Trojan, Bulgaria.
Fell at 6:20 p.m. on Apr. 28, 1904.
Five or six stones aggregating 5.7 kilograms weight and the largest 3.8 kilograms.

GUTERSLOH, Westphalia, Germany.
Fell 8 p.m. on Apr. 17, 1851.
A single stone of 1 kilogram weight.

HARAIYA, Basti district, United Provinces, India.
Fell in August or September, 1878.
One stone of about 1 kilogram weight.

HARIPURA, Jaipur State, Rajputana, India.
Fell at 9 p.m., Jan. 17, 1921.
Stone, weight not given.

HARRISON COUNTY, Indiana.
Fell at 4 p.m. on March 28, 1859.
A shower of which but four of a total weight of about 750 grams were preserved.

HEDESKOGA, Ystad, Sweden.
Fell at 7:45 p.m., April 20, 1922.
One stone of 3.5 kilograms weight.

HEDJAZ, Arabia.
Fell in the night during the spring of 1910.
Four stones, the largest weighing 4 kilograms.

HEREDIA, San José, Costa Rica.
Fell in the night on Apr. 1, 1857.
A shower of which the largest weighed about 1 kilogram.

HESSLE, Upsala, Sweden.
Fell at 12:30 p.m. on Jan. 1, 1869.
A shower of stones which fell over an oval area 3×9 miles, the largest weighing about 1.8 kilograms. The shower was particularly remarkable for the powdery carbonaceous matter associated with it. (See Plate 39.)

HIGASHI-KOEN, Fukuoka, Chikuzen, Japan.
Fell on August 11, 1897.
One stone of 750 grams weight.

HIGH POSSIL, Glasgow, Lanarkshire, Scotland.
Fell on the morning of April 5, 1804.
One stone of about 4,545 grams weight.

HOLBROOK, Navajo County, Arizona.
Fell at 7:15 p.m. on July 19, 1912.
One of the most remarkable showers on record, numbering over 14,000 separate pieces weighing from the fraction of an ounce to 6,600 grams.

HOLETTA, Addis-Ababa, Abyssinia.
Fell at 11:25 a.m., April 14, 1923.
One stone of 1,415 grams.

HOMESTEAD, Iowa County, Iowa.
Fell at 10:15 p.m. on Feb. 12, 1875.
A shower of over 100 stones of an aggregate weight of

227,270 grams (500 pounds) the largest weighing 33,636 grams (74 pounds.)

Honolulu, Oahu, Hawaiian Islands.
Fell at 10:30 a.m. on Sept. 27, 1825.
Several stones of a total weight unknown. The two largest preserved of about 1.5 kilograms weight.

Hungen, Hesse, Germany.
Fell at 7 a.m. on May 17, 1877.
But two stones found weighing 86 and 26 grams.

Hvittis, Abo, Finland.
Fell at noon, Oct. 21, 1901.
One stone of 14 kilograms weight.

Ibbenbuhren, Westphalia, Germany.
Fell at 2 p.m. on June 17, 1870.
A stone belonging to the rare group of chladnites of which less than half a dozen are known. Total weight about 2 kilograms.

Indarch, Shusha, Elisavetpol, Transcaucasia.
Fell at 8:10 p.m. on Apr. 17, 1891.
A stone of about 27 kilograms.

Itapicuru-Mirim, Maranhao, Brazil.
Fell in March, 1879.
One stone of about 2 kilograms weight.

Jackalsfontein, Beaufort West, Cape Province, South Africa.
Fell at 11:30 a.m. on Apr. 22, 1903.
Two stones, weight not given.

Jajh deh Kot Lalu, Faizganj taluk, Khairpur State, Sind, India.
Fell between 5 and 6 p.m., May 2, 1926.
Two pieces recovered weighing 220 and 753 grams.

Jamkheir, Ahmadnagar district, Bombay, India.
Fell at noon on Oct. 5, 1866.
Two small stones, weight not given.

JELLICA, Serbia.
Fell at 2:30 p.m. on Dec. 1, 1889.
A shower of stones belonging to the rare group of amphoterites. The individual stones weighed from a few grams to 8.5 kilograms.

JHUNG, Punjab, India.
Fell at 3 p.m. in June, 1873.
Four stones weighing altogether some 13 pounds or 6 kilograms.

JODZIE, Panevezys, Kovno, Lithuania.
Fell at 4:30 a.m. on June, 1887.
A single stone of weight unknown; all but a few fragments being lost.

JOHNSTOWN, Weld County, Colorado.
Fell at 4:20 p.m., July 6, 1924.
Twenty-seven stones, of which about 40.5 kilograms were recovered, the largest weighing 23.5 kilograms. Belongs to the rare group of diogenites.

JONZAC, Charente Inférieure, France.
Fell at 6 a.m. on June 13, 1819.
A shower of stones belonging to the class of eukrites, of which but four representatives were then known. The two largest stones weighed but 2 and 3 kilograms.

JUDESEGERI, Tumkur district, Mysore, India.
Fell in the evening of Feb. 16, 1876.
A single stone of which but about 750 grams were preserved.

JUVINAS, Libonnès, Antraigues, Ardèche, France.
Fell at 3 p.m. on June 15, 1821.
One stone of over 91 kilograms weight, belonging with that of Jonzac above to the class of eukrites.

KABA, Debreezen, Hungary.
Fell at 10 p.m. on Apr. 15, 1875.
A single stone weighing about 3 kilograms.

KADONAH, Agra district, United Provinces, India.
Fell on the night of Aug. 7, 1822.
A large stone, but weight not recorded.

PLATE 39

A completely encrusted individual from the meteoric shower at Hessle, Sweden, Jan. 1, 1869. Weight 282 grams. A large number of stones fell which were distributed over an area of some 3 × 9 miles, some of them falling on thin ice without breaking it or being broken. In this respect the fall stands in marked contrast with that of Kilbourn.
(See p. 18)

Meteoric stone. Natural size. Fell at Kilbourn, Wisconsin, June 16, 1911, penetrating three thicknesses of shingles and two boards of the roof and floor of a barn. When first picked up, it is stated to have been too warm to hold comfortably. As the stone is small it would seem probable that it was travelling at a very high rate of speed and in a retrograde direction

Kagarlyk, Kiev dist., Kiev govt., Russia.
Fell at 7 a.m., June 30, 1908.
One stone of about 1.9 kilograms.

Kakangari, Tirupathurt taluk, Salem, Madras, India.
Fell at 8 a.m. on June 4, 1890.
Two small stones, total weight unknown; about 340 grams saved.

Kakowa, Oravicza, Krassó-Szörény, Rumania.
Fell at 8 a.m. on May 19, 1858.
A single fragment of 577 grams only.

Kalumbi, Satara district, Bombay, India.
Fell on Nov. 4, 1879.
One stone of about 4½ kilograms weight.

Kamsagar, Shimoga district, Mysore, India.
Fell at 1 p.m. on Nov. 12, 1902.
One stone of 1,293 grams weight.

Karakol, Ayagus, Semipalatinsk, Siberia.
Fell at noon on May 9, 1840.
A single stone of about 3 kilograms weight.

Karkh, Jhalawan, Baluchistan, India.
Fell at 1 p.m. on Apr. 27, 1905.
Six pieces found, weighing 22 kilograms.

Kerilis, Maël Pestivien, Callac, Côtes-du-Nord, France.
Fell at 10:30 a.m. on Nov. 26, 1874.
One stone of about 5 kilograms weight.

Kernouve, Morbihan, France.
Fell at 10 p.m. on May 22, 1869.
A single stone of about 80 kilograms weight.

Kesen, Rikuzen, Japan.
Fell at 5 a.m. on June 12, 1850.
A single stone of about 135 kilograms weight.

Khairpur, Bahawalpur State, Punjab, India.
Fell at 5 a.m. on Sept. 23, 1873.
A shower of stones scattered over an area of 3×16 miles.
Total weight about 30 pounds or 13.64 kilograms.

Kharkov, Ukraine.
Fell at 3 p.m. on Oct. 12, 1787.
Several stones fell, but one preserved.

Kheragur, S. E. of Bhurtpur, Agra district, United Provinces, India.
Fell March 28, 1860.
A single small stone stated to have weighed about 1 pound.

Khetri, Shekhawati, Jaipur, Rajputana, India.
Fell at 9 a.m. on Jan. 19, 1867.
A shower of about 40 stones which were mainly broken up by the natives and two small fragments only preserved.

Khohar, Banda district, United Provinces, India.
Fell at 1 p.m., Sept. 19, 1910.
A single stone, so far as known, of which some 9.7 kilograms have been preserved.

Kikino, Vyazma, Smolensk, Russia.
Fell in 1809.
A single stone of unknown weight.

Kilbourn, Columbia County, Wisconsin.
Fell at 5 p.m. on June 16, 1911.
A single small stone of 772 grams fell upon the roof of a barn and passed through two hemlock boards. The force of the blow was quite unusual for so small a stone. (See Plate 40.)

Killeter, County Tyrone, Ireland.
Fell at 3:30 p.m. on Apr. 29, 1844.
A shower of stones, of which but a few fragments were preserved.

Klein-Wenden, Nordhausen, Erfurt, Germany.
Fell at 4:45 p.m., Sept. 16, 1843.
A single stone of about 3.25 kilograms weight.

Knyahinya, Nagy-Bereszna, Ungvar, Czechoslovakia.
Fell at 5 p.m. on June 9, 1866.
A shower of stones, estimated at over 1,000 in number, of a total weight of 500 kilograms; the largest single

individual, weighing 293 kilograms, penetrated the earth to the depth of 11 feet.

KRÄHENBERG, Zweibrücken, Rhenish Bavaria.
Fell at 6:30 p.m., on May 5, 1869.
A single stone of about 16.5 kilograms.

KRASNAI-UGOL, Ryazan, Russia.
Fell at 2 p.m., Sept. 9, 1829.
Seven stones, of which but two were preserved.

KULESCHOVKA, Poltava, Ukraine.
Fell at 11 a.m. on March 12, 1811.
One stone of over 6 kilograms.

KULP, Kasachsky dist., Elisavetpol, Caucasus.
Fell March 29, 1906.
Two stones of 3.5 and 7-8 kilograms.

KUSIALI, Kumaon, United Provinces, India.
Fell 5 a.m. on June 16, 1860.
One stone fell and was so badly shattered that but a few grams have been preserved.

KUTTIPPURAM, Ponnani taluk, Malabar district, Madras, India.
Fell about 7 a.m. on Apr. 6, 1914.
A shower of stones the total weight of which was about 45.5 kilograms.

KYUSHU, Japan.
Fell at 3 p.m. on Oct. 26, 1886.
A shower of stones of unknown total weight. The largest 29 kilograms.

LA BECASSE, Dun-le-Poëlier, Indre, France.
Fell at noon on Jan. 31, 1879.
A single stone of 2.8 kilograms weight.

LABOREL, Drôme, France.
Fell at 8 p.m., June 14, 1871.
Two stones of 2,091 grams.

LA CHARCA, Irapuato, Guanajuato, Mexico.
Fell at 11:30 a.m. on June 11, 1878.
A single stone of 399 grams.

La Colina, Gen. Lamadrid dept., Buenos Aires, Argentina.
Fell at 11:30 p.m., March 19, 1924.
One stone of 2 kilograms weight.

L'Aigle, Orne, France.
Fell at 1 p.m. on Apr. 26, 1803.
A shower of some 2,000 or 3,000 stones and of an aggregate weight of 37 kilograms. This fall is of historic interest, since as noted on p. 11 it served to satisfy all doubts as to the ultraterrestrial source of meteorites.

Lakangaon, Nimar, Indore, Central India.
Fell at 6 p.m. on Nov. 24, 1910.
A single stone belonging to the rare group of eukrites.
But 212.5 grams known, of which 116 are in Calcutta.

Lalitpur, Lalitpur district, United Provinces, India.
Fell at 10:30 a.m. on April 7, 1887.
A single stone which broke into pieces in falling, but 372 grams recovered.

Lance, Vendôme, Loir-et-Cher, France.
Fell at 5:20 p.m. on July 23, 1872.
A shower of stones of which half a dozen were recovered, weighing altogether 51.75 kilograms; the largest single individual weighing 47 kilograms is in the Vienna Natural History Museum.

Lançon, Bouches-du-Rhône, France.
Fell at 8:30 p.m. on June 20, 1897.
About 7 kilograms known.

Lanzenkirchen, Wiener Neustadt, Lower Austria.
Fell at 7:25 p.m., Aug. 28, 1925.
One stone weighing 5 kilograms.

Launton, Bicester, Oxfordshire, England.
Fell at 7:30 p.m. on Feb. 15, 1830.
A single stone of 1.02 kilograms.

Leeuwfontein, Pretoria, Transvaal, South Africa.
Fell at 2 p.m., June 21, 1912.
But 460 grams known.

Leighton, Colbert County, Alabama.
Fell at 8 p.m., Jan. 12, 1907.
A single stone of 877 grams weight.
Leonovka, Novgorod-Syeversk dist., Chernigov govt., Ukraine.
Fell Aug. 23, 1900.
Two stones recorded.
Le Pressoir, Indre-et-Loire, France.
Fell at 3 p.m. on Jan. 25, 1845.
One stone weighing 3 kilograms, found.
Les Ormes, Yonne, France.
Fell at 5 p.m. on Oct. 1, 1857.
A single stone of about 125 grams only known.
Lesves, Namur, Belgium.
Fell at 7:30 a.m.
One stone of about 2 kilograms.
Le Teilleul, Manche, France.
Fell at 3 p.m., April 13, 1896.
780 grams known of which 750 grams are in the Paris Museum.
Limerick County, Ireland.
Fell at 9 a.m., Sept. 10, 1813.
Several stones, the 3 largest of which weighed 17, 24, and 65 pounds.
Linum, Fehrbellin, Brandenburg, Germany.
Fell at 8 p.m. on Sept. 5, 1854.
One stone of 1,862 grams.
Lissa, Bunzlau, Bohemia.
Fell at 3:30 p.m., Sept. 3, 1808.
Four stones of a total weight of about 10.4 kilograms.
Little Piney, Pulaski County, Missouri.
Fell at 3:30 p.m. on Feb. 13, 1839.
One stone only, weighing about 22.8 kilograms.
Lixna, Dvinsk (= Daugavpils, Dünaburg) Latvia.
Fell at 5:30 p.m. on July 12, 1820.
One stone of 40 pounds (18.14 kilograms) was recovered, the others falling in the water.

LODRAN, Multan, Punjab, India.
Fell at 2 p.m., Oct. 1, 1868.
One stone of unknown weight, about 1 kilogram preserved.

LOS MARTINEZ, Cervera, Murcia, Spain.
Fell May, 1894.
But 25 grams reported in Madrid Museum.

LUCE, Sarthe, France.
Fell at 4:30 p.m., Sept. 13, 1768.
One stone of 3.5 kilograms.

LUMPKIN, Stewart County, Georgia.
Fell at 11:45 a.m. on Oct. 6, 1869.
One stone of about 34 grams weight.

LUNDSGARD, Ljungby, Gottland, Sweden.
Fell at 8:30 p.m. on April 3, 1889.
One stone of about 11 kilograms.

LUOTOLAX, Viborg, Finland.
Fell Dec. 13, 1813.
A shower of stones falling on the surface of the ice on a lake. But few recovered.

LUPONNAS, Ain, France.
Fell at 1 p.m., Sept. 7, 1753.
Two stones weighing 5.89 kilograms. Mostly destroyed and lost.

MACAO, Rio Grande do Norte, Brazil.
Fell at 5 a.m. on Nov. 11, 1836.
A shower of stones weighing from 1 to 80 pounds each.

MADRID, Spain.
Fell at 9:30 a.m. on Feb. 10, 1896.
Several small stones weighing altogether about 400 grams.

MANBHOOM, Bengal, India.
Fell at 9 a.m. on Dec. 22, 1863.
Several stones of varying weights up to 15 kilograms, belonging to the group of amphoterites of which but 3 representatives are known.

MANEGAON, Bhusawal, East Khandesh district, Bombay, India.
Fell at 3:30 p.m. on June 29, 1843.
One stone about 5×15 inches in size which became broken in the fall and mostly lost, belonging to the rare group called diogenites by Prior.

MARIAVILLE, Rock County, Nebraska.
Fell at midnight on Oct. 16, 1898.
But 340 grams known.

MARION, Linn County, Iowa.
Fell at 2:45 p.m. on Feb. 25, 1847.
Three stones weighing 21, 20, and 40 pounds.

MARJALAHTI, Viborg, Finland.
Fell at 10 p.m. on June 1, 1902.
A single stone of about 45 kilograms which was shattered in falling.

MARMANDE, Lot-et-Garonne, France.
Fell on July 4, 1848.
Known only from fragments found in collections.

MASCOMBES, Corrèze, France.
Fell at midnight, on Jan. 31, 1835.
A single stone of about 1 kilogram weight.

MASSING, Eggenfelden, Lower Bavaria, Germany.
Fell at 10:30 a.m. on Dec. 13, 1803.
A single stone of about 1.6 kilograms of which very little was preserved.

MAUERKIRCHEN, Upper Austria.
Fell at 4 p.m. on Nov. 20, 1786.
A stone of about 18 kilograms weight.

MAURITIUS, Indian Ocean.
Fell on Dec. 22, 1801.
Three stones, weight not given, belonging to the howarditic chondrite group.

MEERUT, Meerut district, United Provinces, India.
Fell about 1860-62.
But 22 grams known.

Meester-Cornelis, Batavia, Java.
Fell between 6 and 6:15 a.m., June 2, 1915.
One stone of 24.75 kilograms weight.

Menow, Alt-Strelitz, Mecklenburg, Germany.
Fell at 12:30 p.m. on Oct. 7, 1862.
One stone of about 10.5 kilograms weight.

Mern, Praesto, Denmark.
Fell at 2:30 p.m., Aug. 29, 1878.
One stone of 4 kilograms weight.

Merua, Allahabad, United Provinces, India.
Fell at 11:15 a.m., Aug. 30, 1920.
Six stones weighing together 71.4 kilograms.

Meuselbach, Thuringia, Germany.
Fell at 7:45 p.m. on May 19, 1897.
One small stone of but 870 grams weight.

Mezö-Madaras, Transylvania.
Fell at 4:30 p.m. on Sept. 4, 1852.
A shower giving a total weight of about 22.7 kilograms, the largest weighing about 10 kilograms.

Mhow, Azamgarh district, United Provinces, India.
Fell at 3 p.m. on Feb. 16, 1827.
Four or five stones, one of which it is stated hit a man in falling. The largest weighed 1.8 kilograms.

Middlesbrough, Yorkshire, England.
Fell at 3:35 p.m. on March 14, 1881.
One stone of about 1.6 kilograms.

Mighei, Olviopol, Kherson, Ukraine.
Fell at 8:30 a.m. on June 18, 1889.
A stone the exact weight not known but represented by 8 kilograms of fragments.

Milena, Varazdin, Croatia, Yugoslavia.
Fell at 3 p.m., April 26, 1842.
Two or three stones of 5 to 6 kilograms weight.

Minnichhof, Oedenburg, Hungary.
Fell at 10:45 a.m., May 27, 1905.
One stone, weight not given.

PLATE 41

Meteoric Stone. One of the larger individuals of the fall at Modoc, Kansas, on September 2, 1905. Weight 2,268 grams

MIRZAPUR, Ghazipur district, United Provinces, India.
Fell at 11:30 a.m. on Jan. 7, 1910.
One stone of which two pieces weighing 208.5 grams and 8.3 kilograms were recovered.

MISSHOF, Courland, Latvia.
Fell at 3:30 p.m. on April 10, 1890.
One stone of about 5.8 kilograms.

MJELLEIM, Hyen, Nordfjord, Norway.
Fell between 2 and 3 p.m., Jan. 24, 1898.
Probably a shower, but only a single stone found weighing about 100 grams.

MOCS, Cluj (=Klausenburg, Kolozsvar) Transylvania.
Fell at 4 p.m. on Feb. 3, 1882.
A shower of some 3,000 (estimated) stones of a total weight of 300 kilograms. The largest single individual weighed about 56 kilograms. This is one of the most widely distributed falls, portions of it at one time being found in over 100 private and public collections.

MODOC, Scott County, Kansas.
Fell at 9:30 p.m. on Sept. 2, 1905.
A fall of 15-20 stones, the largest of which weighed 4.86 kilograms, totaling about 16 kilograms. (See Plate 41.)

MOKOIA, Taranaki, North Island, New Zealand.
Fell at 12:30 p.m. on Nov. 26, 1908.
Several stones of but a few pounds each and but two of which were recovered.

MOLINA, Murcia, Spain.
Fell on Dec. 24, 1858.
One stone of 114 kilograms weight.

MONROE, Cabarrus County, North Carolina.
Fell at 3 p.m. on Oct. 31, 1849.
One stone of about 8.64 kilograms.

MONTE MILONE, Macerata, Italy.
Fell at 9:15 a.m. on May 8, 1846.
Several stones of which five were recovered.

MONTLIVAULT, Loir-et-Cher, France.
Fell in the day on July 22, 1838.
One stone of but about 0.5 kilogram weight.

MOORESFORT, County Tipperary, Ireland.
Fell at noon in August, 1810.
One stone of 3.52 kilograms weight.

MORADABAD, Moradabad district, United Provinces, India.
Fell in 1808.
But about 70 grams of this fall known.

MORNANS, Bourdeaux, Drôme, France.
Fell in September, 1875.
One stone of 1.3 kilograms weight.

MOTI-KA-NAGLA, Goordha, Biana district, Bharatpur, India.
Fell at 5 p.m. on Dec. 22, 1868.
A shower of stones but only 3 found, of which the largest weighed 1.43 kilograms.

MOTTA DI CONTI, Casale, Piedmont, Italy.
Fell at 11 a.m. on Feb. 29, 1868.
Several stones of about 9.15 kilograms weight.

MOUNT BROWNE, County Evelyn, New South Wales.
Fell at 9:30 a.m. on July 17, 1902.
One stone of about 11.5 kilograms.

MUDDOOR, Mysore, India.
Fell at 7 a.m. on Sept. 21, 1865.
Two stones, one of which weighed about 2 kilograms, the second being broken in pieces.

MULLETIWU, Northern Province, Ceylon.
Fell on April 13, 1795.
A shower of which the 25 gram piece in the Paris Museum is all there is known.

MURAID, Ghatail sub-division, Mymensingh dist., Bengal, India.
Fell at 2:30 p.m., Aug. 7, 1924.
Two stones, one broken in halves, weight 4,693 grams.

Myhee Caunta, Ahmadabad, Bombay, India.
Fell at 4 p.m. on Nov. 30, 1842.
Several stones of a weight unknown.

Nagaria, Fatehabad pargana, Agra district, United Provinces, India.
Fell 1½ hours after sunrise on April 24, 1875.
One stone of about 11.8 kilograms almost wholly broken up and lost. But 20 grams preserved. A stone of more than usual interest belonging to the group of eukrites of which less than half a dozen are known.

Nagy Borové, Liptó, Czechoslovakia.
Fell on May 9, 1895.
But two small pieces known.

Nakhla, Abu Hommos, Alexandria, Egypt.
Fell at 9 a.m. on June 28, 1911.
About 40 stones totaling about 40 kilograms, of a unique stone consisting of a crystalline aggregate of olivine and diopside.

Nammianthal, South Arcot district, Madras, India.
Fell on January 27, 1886.
One stone of about 4.5 kilograms.

Nanjemoy, Charles County, Maryland.
Fell at noon on Feb. 10, 1825.
One stone of 7.5 kilograms weight and of which but 2,525 grams are known in collections.

Nann Yang Pao, southeastern Kansu, China.
Fell at 12 noon, July 11, 1917.
One stone weighing 53.2 kilograms.

Nawapali, Sambalpur district, Central Provinces, India.
Fell at 6 p.m. on June 6, 1890.
Three stones fell but only a trifle over 60 grams preserved.

Nerft, Courland, Latvia.
Fell at 4:45 a.m. on April 12, 1864.
Two stones of about 4.75 and 5.5 kilograms weight.

New Concord, Muskingum County, Ohio.
Fell at 12:45 p.m. on May 1, 1860.
A shower of some 30 stones of which the largest weighed about 47 kilograms and the total weight of which was about 500 pounds. It was from stones of this fall that was first identified and separated the new mineral merrillite.

Ngawi, Madioen, Java.
Fell at 5:15 p.m. on Oct. 3, 1883.
Two stones of about 1,303 grams weight.

Nio, west of Yamaguch, Yoshiki, Suwo, Japan.
Fell at 10:30 p.m. on Aug. 8, 1897.
Two stones weighing together 448 grams.

N'Kandhla, Zululand, Natal, South Africa.
Fell at 1:30 p.m. on Aug. 1, 1912.
One stone of about 17.3 kilograms weight.

Nobleborough, Lincoln County, Maine.
Fell at 4:30 p.m. on Aug. 7, 1823.
One stone of about 2.3 kilograms. Was badly broken and but 78 grams preserved.

Nogoya, Entre Rios, Argentina.
Fell in the evening of June 30, 1879.
One stone of about 4 kilograms.

Novy-Ergi, Novgorod govt., Russia.
Fell at 4 p.m., Dec. 10, 1662.
A shower of stones.

Novy-Projekt, Novo-Alexandrovsky dist., Kovno, Lithuania.
Fell at 2 a.m., April 25, 1908.
One stone of about 1,000 grams.

Novy-Urei, Karamzinka, Nijni-Novgorod, Russia.
Fell at 7:15 a.m. on Sept. 4, 1886.
Three stones of which some 2 kilograms have been preserved. A rare type of which but 3 are known.

NULLES, Catalonia, Spain.
Fell at 5:30 p.m. on Nov. 5, 1851.
A large number of stones reported as fallen but few preserved of which the largest weighed about 9 kilograms.
OCHANSK, Perm, Russia.
Fell at 1 p.m. on Aug. 30, 1887.
A shower of stones aggregating over 500 kilograms in weight, the largest weighing 115 kilograms.
OESEL Island, Esthonia, Baltic States.
Fell at 3:30 p.m. on May 11, 1855.
Several stones fell but only about 6 kilograms of one saved.
Ó-FEHÉRTÓ, Nyiregyhaza, Szabolcs, Hungary.
Fell on July 25, 1900.
One stone of about 3.2 kilograms weight.
OGI, Hizen, Kyushu, Japan.
Fell at 11 a.m., June 8, 1741.
Four stones fell of some 14.2 kilograms weight. Two of these were for a long time subjects of annual offerings in a temple.
OHABA, Alba Iulia (=Karlsburg), Transylvania.
Fell at 12:15 a.m. on Oct. 11, 1857.
One stone of 16.25 kilograms weight.
OKNINY, Krzemieniec, Wolyn, Poland.
Fell at 9:30 a.m. on Jan. 8, 1834.
One stone of about 12 kilograms, only a small portion of which was preserved.
OLIVA-GANDIA, Valencia, Spain.
Fell May 26, 1520.
Three stones reported to have fallen.
OLIVENZA, Badajoz, Spain.
Fell at 8 a.m., June 19, 1924.
Five stones fell of a total weight of 150 kilograms.
ORANGE RIVER, South Africa.
Fell Sept. 8, 1887.
One stone, original weight unknown and but about 8 grams known.

Orgueil, Montauban, Tarn-et-Garonne, France.
Fell at 8 p.m. on May 14, 1864.
Some 20 stones the total weight of which is not known. Some 11.5 kilograms preserved in collections. A carboniferous chondrite of more than ordinary interest. It was in this stone that was found the mineral breunnerite, the only known occurrence of a carbonate in a meteorite.

Ornans, Doubs, France.
Fell at 7:15 p.m., on July 11, 1868.
One stone of about 6 kilograms weight.

Orvinio, Rome, Italy.
Fell 5:15 a.m., Aug. 31, 1872.
Several stones from which six fragments were saved weighing 3.4 kilograms.

Otomi, Yamagata, Japan.
Fell May 24, 1867.
One stone of 6.5 kilograms weight.

Ottawa, Franklin County, Kansas.
Fell at 6:15 p.m. on April 9, 1896.
One stone of 840 grams weight.

Oviedo, Asturias, Spain.
Fell at 5:45 p.m. on August 5, 1856.
Three fragments weighing 205 grams are all that is known of this fall.

Pacula, Jacala, Hidalgo, Mexico.
Fell the morning of June 18, 1881.
5.4 kilograms known of this stone.

Palahatchie, Rankin County, Mississippi.
Fell Oct. 17, 1910.
One small stone, weight not given.

Pampanga, Philippine Islands.
Fell on April 4, 1859.
One stone, original weight not known, but 165 grams accounted for in the collections.

PARNALLEE, Madura district, Madras, India.
Fell at noon, Feb. 28, 1857.
Two stones of about 17 and 61 kilograms.

PAVLOGRAD, Ekaterinoslav, Ukraine.
Fell May 19, 1826.
One stone of 40 kilograms weight.

PAVLOVKA, Balashey, Saratov, Russia.
Fell at 5 p.m. on Aug. 2, 1882.
One stone of 2 kilograms weight.

PERAMIHO, Ungoni, Tanganyika Territory, East Africa.
Fell at 7 a.m. on Oct. 24, 1899.
One stone of 165 grams weight.

PERTH, SCOTLAND.
Fell at 12:30 p.m. on May 17, 1830.
A stone said to have been 7 inches in diameter fell, but only two small pieces weighing about 2 grams preserved.

PETERSBURG, Lincoln County, Tennessee.
Fell at 5:30 p.m. on Aug. 5, 1855.
One stone of about 1.8 kilograms weight.

PHU-HONG, Binh-Chanh, Cochin China.
Fell on Sept. 22, 1887.
One small stone of but about 500 grams weight.

PILLISTFER, Livonia, Latvia.
Fell at 12:30 p.m. on Aug. 8, 1863.
Four stones found weighing about 23.25 kilograms.

PIRGUNJE, Dinajpur district, Bengal, India.
Fell on Aug. 29, 1882.
One stone of 842 grams weight.

PIRTHALLA, Hissar district, Punjab, India.
Fell at 2:30 p.m. on Feb. 9, 1884.
One stone of about 1.36 kilograms weight.

PLOSCHKOVITZ, Litomerice, Bohemia.
Fell at 2 p.m., June 22, 1723.
A shower of 33 stones of which but a single piece, 1¼ ounces, is known with certainty.

PNOMPEHN, Cambodia, French Indo-China.
Fell at 3 p.m., June 20-23, 1868.
Three stones of one of which but 41 grams are preserved.

POHLITZ, Gera, Reuss, Germany.
Fell at 8 a.m., Oct. 13, 1819.
One stone of about 3 kilograms weight.

POKHRA, Basti district, Gorakhpur, United Provinces, India.
Fell at 8:30 p.m., May 27, 1866.
One stone of but 350 grams weight.

PONTA GROSSA, Paraná, Brazil.
Fell in April, 1846.
One stone of 667 grams weight.

PORTUGAL.
Fell Feb. 19, 1796.
One stone of about 4.5 kilograms.

PRICETOWN, Highland County, Ohio.
Fell Feb. 13, 1893.
One stone of but 900 grams weight.

PULSORA, Ratlam State, Central India.
Fell in the afternoon on March 16, 1863.
One stone weighing 680 grams.

PULTUSK, Warsaw, Poland.
Fell at 7 p.m. on Jan. 30, 1868.
A shower of stones estimated at over 100,000 pieces of which the largest weighed 9 kilograms. One of the most remarkable falls on record. Over 200 kilograms are listed as scattered throughout the various collections of the world.

QUEENS MERCY, Matatiele, Griqualand, East, Cape Province, South Africa.
Fell at 8 p.m., April 30, 1925.
Three stones, one large, total weight unknown.

QUENGGOUK, Bassein district, Lower Burma.
Fell at 2:30 a.m. on Dec. 27, 1857.
Three fragments belonging to the same mass fell weighing respectively 2,291, 1,909½, and 1,844½ grams.

QUINCAY, Vienne, France.
Fell in the summer of 1851.
Nothing known of the fall and but 31 grams recorded in collections.

RAKOVKA, Tula, Russia.
Fell at 3 p.m. on Nov. 20, 1878.
One stone "about as large as a man's head." Weight not given.

RAMPURHAT, Birbhum dist., Bengal, India.
Fell at 9:30 a.m., Nov. 21, 1916.
One stone of 100 grams weight.

RANCHAPAR, Jamtara, Santhal, Bihar, India.
Fell at 8:30 on Feb. 20, 1917.
Four pieces weighing altogether 366.3 grams.

RANCHO DE LA PRESA, Zenapecuaro, Michoacan, Mexico.
Fell in 1899.
But 3 grams known.

RENAZZO, Cento, Ferrara, Italy.
Fell at 8:30 p.m. on Jan. 15, 1824.
Several stones fell, three being recovered, the largest of which weighed 5 kilograms.

RICHARDTON, Stark County, North Dakota.
Fell at 10 p.m. on June 30, 1918.
Several stones of a total weight of about 90.9 kilograms.

RICHMOND, Chesterfield County, Virginia.
Fell at 8:30 a.m. on June 4, 1828.
One stone of about 18.2 kilograms.

RICH MOUNTAIN, Jackson County, North Carolina.
Fell at 2 p.m. on June 30, 1903.
But one fragment weighing 668 grams found.

ROCHESTER, Fulton County, Indiana.
Fell at 8:45 p.m. on Dec. 21, 1876.
An unusually spectacular display over an area of over 1,000 miles yielded but one small stone of about 340 grams weight.

ROSE CITY, Ogemaw County, Michigan.
Fell at 11 p.m., Oct. 17, 1921.
Three stones; total weight 10.5 kilograms.

ROWTON, Wellington, Shropshire, England.
Fell at 3:45 p.m. on April 20, 1876.
One stone weighing 3.41 kilograms.

RUSCHANY, Slonim, Grodno, Poland.
Fell on Dec. 7, 1894. (?).
Fall reported, none of the material extant.

RYECHKI, Sumy district, Kharkov, Ukraine.
Fell at 1:30 p.m. on April 9, 1914.
Two stones of 3.41 and 2.5 kilograms.

SABETMAHET, near Balrampur, Gonda district, United Provinces, India.
Fell in the evening of Aug. 16, 1885.
A stone of about 2 kilograms weight fell and was made an object of worship. But 3 grams were secured and preserved in the Calcutta Museum.

ST. CAPRAIS-DE-QUINSAC, Gironde, France.
Fell at 2:45 p.m. on Jan. 28, 1883.
One stone of 282½ grams weight.

ST. CHRISTOPHE-LA-CHARTREUSE, Roche-Servière, Vendée, France.
Fell on Nov. 5, 1841.
One stone of about 5½ kilograms.

ST. DENIS-WESTREM, Ghent, Belgium.
Fell at 7:45 p.m. on June 7, 1855.
One stone of but 700 grams weight.

ST. GERMAIN-EN-PUEL, Vitre, Ille-et-Vilaine, France.
Fell at 3:30 p.m. on July 4, 1890.
One stone of about 4 kilograms.

ST. MARK'S Mission Station, Transkei, Cape Province, South Africa.
Fell at 11 p.m. on Jan. 3, 1903.
One stone of 13.78 kilograms weight.

St. Mesmin, Aube, France.
Fell at 3:45 p.m. on May 30, 1866.
Three stones fell weighing 1.9, 2.2, and 4.2 kilograms respectively.

St. Michel, Finland.
Fell at 7:25 p.m. on July 12, 1910.
Two stones of 7 and 10 kilograms weight respectively.

Salles, Villefranche, Rhone, France.
Fell at 6 p.m. on March 12, 1798.
One stone of about 91 kilograms.

Santa Barbara, Rio Grande, Brazil.
Fell on Sept. 26, 1873.
One stone of about 400 grams.

Santa Isabel, Santa Fé Province, Argentina.
Fell at 9:30 a.m., Nov. 18, 1924.
One stone, weight 5.5 kilograms.

Saratov govt., Russia.
Fell between 4 and 6 p.m., Sept. 11, 1918.
Several stones of total weight of 328 kilograms.

Sauguis, St. Étienne, Basses-Pyrénées, France.
Fell at 2:30 a.m. on Sept. 7, 1868.
One stone from which 2-4 kilograms were preserved. Total weight unknown.

Sauveur, Haute-Garonne, France.
Fell July, 10, 1914.
One stone of about 14 kilograms.

Savtschenskoje, Tiraspol, Kherson, Ukraine.
Fell at 8 p.m. on July 27, 1894.
One stone of about 2.5 kilograms.

Schellin, Stargard, Pomerania, Prussia.
Fell at 4 p.m. on April 11, 1715.
Two stones, the larger weighing 7 kilograms. But 348 grams preserved.

Schonenberg, Pfaffenhausen, Swabia, Bavaria.
Fell at 2 p.m. on Dec. 25, 1846.
One stone of about 8 kilograms weight.

Searsmont, Waldo County, Maine.
Fell at 8:15 a.m. on May 21, 1871.
One stone which broke by impact with ground; original weight about 5.45 kilograms. Only about 1 kilogram preserved which has been scattered through 27 collections in fragments of from 1 to 60 grams, the National collections containing the larger portion in the form of 3 pieces weighing 94.55 grams. The main mass of all, 900 grams weight, is in the museum of Amherst College.

Segowlie, Bettiah, Champaran district, Bihar, India.
Fell at noon on March 6, 1853.
A shower of some 30 stones varying in weights up to 6.5 kilograms.

Sena, Sariñena, Huesca, Spain.
Fell at midnight on Nov. 17, 1773.
One stone of about 4 kilograms.

Seres, Macedonia.
Fell in June, 1818.
One stone of about 8.5 kilograms.

Serra de Mage, Pesqueira, Pernambuco, Brazil.
Fell at 11 a.m. on Oct. 1, 1923.
A shower of stones of which some 50 were recovered. Weight not given.

Sete Lagoas, Minas Geraes, Brazil.
Fell Dec. 15, 1908.
Six small stones, weight not given.

Sevilla, Andalusia, Spain.
Fell on Nov. 1, 1862.
One stone of 100 grams weight.

Sevrukovo, Byelgorod, Kursk, Russia.
Fell at 11:45 p.m. on May 11, 1874.
One large stone of 98 kilograms weight.

Shalka, Bishnupur, Bankrura district, Bengal, India.
Fell at 4:30 p.m. on Nov. 30, 1850.
A large stone said to have measured 3 feet in diameter fell and was broken in pieces by the impact and only

about 36.25 kilograms preserved. The stone belongs to the rare group of diogenites of Prior, and pieces have been eagerly sought by collectors, causing it to be broken and scattered through some 30 collections in bits from mere splinters to a mass of 1.9 kilograms which remains in the Calcutta Museum.

SHARPS, Richmond County, Virginia.
Fell April 1, 1921.
One stone of 1,265 grams weight.

SHELBURNE, Grey County, Ontario, Canada.
Fell at 8 p.m. on Aug. 13, 1904.
Two stones weighing 5.91 and 12.72 kilograms.

SHERGHOTTY, Gya, Bihar, India.
Fell at 9 a.m. on Aug. 25, 1865.
One stone of 5 kilograms.

SHIKARPUR, Purnea dist., Bihar and Orissa prov., India.
Fell at 9 a.m., Aug. 9, 1921.
One stone of about 3,680 grams.

SHUPIYAN, Kashmir, India.
Fell in April, 1912.
Two stones of 0.5 and 4.5 kilograms.

SHYTAL, Madhupur jungle, Mymensingh dist., Bengal, India.
Fell at noon on Aug. 11, 1863.
One stone of about 3.2 kilograms.

SIENA, Tuscany, Italy.
Fell at 7 p.m. on June 16, 1794.
A shower of small stones the largest weighing but about 3.5 kilograms.

SIMMERN, Hunsrück, Rhenish Prussia.
Fell at 9:15 a.m. on July 1, 1920.
A large number of stones scattered over an area of 2×10 miles. But 3 were found weighing 142, 470, and 610 grams respectively.

SIMONOD, Ain, France.
Fell at 9 p.m. on Nov. 13, 1835.
One stone, weight unknown.

Sinai Peninsula, Egypt.
Fell at 2:30 p.m. on July 14-17, 1916.
Two stones reported to have fallen of which but one, weighing 1,455 grams, was preserved.

Sindhri, Khipro taluk, Thar and Parker dists., Bombay, India.
Fell at 11 p.m. on June 10, 1901.
Two stones, one of less than 2 kilograms weight and the other of about 6.6 kilograms.

Sitathali, Raipur dist., Central Provinces, India.
Fell at 11 a.m. on March 4, 1875.
Two stones of total weight of 1.15 kilograms.

Ski, Akershuus, Christiania, Norway.
Fell in the evening of Dec. 27, 1848.
One small stone weighing 850 grams.

Slavetic, Zagreb, Croatia, Yugoslavia.
Fell at 10:30 a.m. on May 22, 1868.
Several stones that were said to have fallen, but two preserved weighing 1,708 grams.

Slobodka, Yukhnov, Smolensk, Russia.
Fell on Aug. 10, 1818.
One stone of about 2.75 kilograms weight.

Soko-Banja, Aleksinac, Serbia.
Fell at 2 p.m. on Oct. 13, 1877.
Some 10 stones found scattered over an area 7×1 miles and weighing altogether about 80 kilograms.

Sone, Shuchi, Funai, Tamba, Japan.
Fell at noon on June 7, 1866.
One stone of 17 kilograms weight.

Stalldalen, Nya Kopparberg, Orebro, Sweden.
Fell at 11:30 p.m., June 28, 1876.
Eleven stones of a total weight of about 34 kilograms, the largest weighing about 12.5 kilograms.

Stannern, Iglau, Moravia, Czechoslovakia.
Fell at 6 a.m. on May 22, 1808.
A shower of 200-300 stones mostly small and of a total weight of about 52 grams. It belongs to the rare

class of eukrites and has been the subject of many papers and is broken and scattered throughout nearly 100 collections.

STAVROPOL, north side of the Caucasus, Russia.
Fell at 5 p.m. on March 24, 1857.
One stone weighing about 1.5 kilograms.

STRATHMORE, Perthshire, Scotland.
Fell at 1.15 p.m. on Dec. 3, 1917.
Four stones fell weighing all told 13.41 kilograms.

SULTANPUR, Ballia dist., United Provinces, India.
Fell at 11 a.m., July 10, 1916.
Several stones of a total weight of 1,710 grams.

SUPUHEE, Padrauna, Gorakhpur dist. United Provinces, India.
Fell at noon on Jan. 19, 1865.
Six stones fell, but 5 preserved weighing about 7 kilograms.

TABOR, Bohemia.
Fell at 8 p.m. on July 3, 1753.
A shower of many stones the largest weighing about 6 kilograms.

TADJERA, Sétif, Constantine, Algeria.
Fell at 10:30 p.m. on June 9, 1867.
Two stones of 3 and 6 kilograms (est.) respectively. Of particular interest on account of black color which Meunier considers due to heating.

TAKENOUCHI, Yabu, Tajima, Japan.
Fell at 5:30 a.m. on Feb. 18, 1880.
One stone of about 750 grams.

TANE, Lake Biwa, Shiga, Omi, Japan.
Fell at 2:28 p.m. on Jan. 25, 1918.
One stone of 311 grams.

TENNASILM, Esthonia, Baltic States.
Fell at noon on June 28, 1872.
One stone of about 28.5 kilograms.

TIESCHITZ, Prerov, Moravia, Czechoslovakia.
Fell at 1:45 p.m. on July 15, 1878.
One stone of 28 kilograms weight.

Timochin, Yukhnov, Smolensk, Russia.
Fell at 3 p.m. on March 25, 1807.
One stone of 65.5 kilograms weight.

Tjabé, Padang, Rembang, Java.
Fell at 9 p.m. on Sept. 19, 1869.
A stone of 20 kilograms.

Tjerebon, Java.
Fell at 10:30 p.m., July 10, 1922.
Two stones weighing 16.5 kilograms.

Tomakovka, Ekaterinoslav, Ukraine.
Fell at 9:30 p.m. on Jan. 17, 1905.
Several small stones. Total weight not given.

Tomatlan, Jalisco, Mexico.
Fell at 4:30 p.m. on Sept. 17, 1879.
Two or three stones, the largest weighing less than a kilogram.

Tonk, Rajputana, India.
Fell at 3:55 p.m. on Jan. 22, 1911.
A shower of small stones of which only 7.7 grams were collected.

Toulouse, Haute Garonne, France.
Fell at 8 p.m. on April 10, 1812.
A small shower eight of which were found, the largest weighing about 1 kilogram.

Tounkin, Tunka, Irkutsk, Siberia.
Fell at 7 a.m., Feb. 18, 1824.
One stone of about 2 kilograms.

Tourinnes-la-Grosse, Tirelmont, Belgium.
Fell at 11:30 a.m., Dec. 7, 1863.
Two stones, one of 7 and one of 7.5 kilograms weight.

Trenzano, Brescia, Italy.
Fell at 4 p.m., Nov. 12, 1856.
Three stones said to have fallen but two found, the largest weighing 9 kilograms.

Treysa, Hesse, Germany.
Fell at 3:30 p.m., April 3, 1916.
One stone of 63 kilograms weight.

Troup, Smith County, Texas.
Fell on the morning of April 26, 1917.
One stone of about 1 kilogram weight.

Tuan Tuc, Cochin China.
Fell at 3 p.m., June 30, 1921.
Four stones fell, total weight not given.

Tysnes Island, Hardanger Fiord, Norway.
Fell at 8:30 p.m., May 20, 1884.
Two stones, the larger weighing 18.95 kilograms and the smaller but 910 grams.

Uberaba, Minas Geraes, Brazil.
Fell at 10 a.m., June 29, 1903.
One stone of 30-40 kilograms.

Uden, North Brabant, Holland.
Fell at 10:30 a.m., June 12, 1840.
One stone of but 710 grams weight.

Udipi, South Kanara district, Madras, India.
Fell at 10 a.m., April, 1866.
One stone of about 3.63 kilograms.

Umbala, Punjab, India.
Fell 1822-3.
One stone of about 100 grams.

Utrecht, Holland.
Fell at 8 p.m., June 2, 1843.
Two stones weighing 2.7 and 7 kilograms.

Vago, Verona, Italy.
Fell on June 21, 1668.
A shower of doubtful authenticity.

Valdinizza, Pavia, Italy.
Fell at 10 a.m., July 12, 1903.
One stone of 131 grams weight.

Vavilovka, Kherson, Ukraine.
Fell at 2 p.m., June 19, 1876.
One stone of about 16 kilograms weight, belonging to the rare group of amphoterites.

VERKHNE TSCHIRSKAIA, Region of Don Cossacks, Russia.
Fell at midday, Nov. 12, 1843.
One stone of about 8 kilograms weight.

VERNON COUNTY, Wisconsin.
Fell at 9 a.m., March 26, 1865.
Two stones of 700 and 800 grams weight.

VIGARANO, Ferrara, Italy.
Fell at 9:30 p.m., Jan. 22, 1910.
Two stones of about 4.5 and 11.5 kilograms weight.

VILLARRIRA, Paraguay.
Fell at 7 p.m., July 20, 1925.
One stone, weight not given.

VIRBA, Vidin, Bulgaria.
Fell on June 1, 1873.
One stone of 3.6 kilograms weight.

VISHNUPUR, Bankura district, Bengal, India.
Fell at 9:30 a.m., Dec. 15, 1906.
Two stones of 670 and 1767 grams weight.

VISUNI, Umarkot, Thar and Parkar dist., Sind, India.
Fell at noon, Jan. 19, 1915.
One stone of 594 grams weight.

VOUILLÉ, Poitiers, Vienne, France.
Fell at 11 p.m., May 13, 1831.
One stone of about 20 kilograms weight.

WALKRINGEN, Bern, Switzerland.
Fell between 7 and 8 p.m., May 18, 1698.
One stone, no further record.

WARRENTON, Warren County, Missouri.
Fell at 7:15 a.m., Jan. 3, 1877.
One stone estimated to have weighed about 100 pounds but of which only about 1,600 grams are known.

WESSELY, Hradisch, Moravia, Czechoslovakia.
Fell at 3:30 p.m., Sept. 9, 1831.
One stone of about 3.75 kilograms weight.

WESTON, Fairfield County, Connecticut.
Fell at 6:30 a.m., Dec. 14, 1807.

Several stones of an estimated total weight of 330 pounds but largely broken up and lost. Of interest as being the first stone to have been observed to fall and to have been described in America.

WITKLIP, Carolina district, Transvaal, South Africa.
Fell at 9:40 a.m., May 26, 1918.
One stone fell, but of this but four fragments weighing altogether but 22 grams preserved.

WITTEKRANTZ, Beaufort West, Cape Province, South Africa.
Fell at 8 a.m., Dec. 9, 1880.
Two stones, the larger weighing about 2 kilograms.

WOLD COTTAGE, Thwing, Scarborough, Yorkshire, England.
Fell at 3:30 p.m., Dec. 13, 1795.
One stone of about 25.5 kilograms weight.

YATOOR, Nellore, Madras, India.
Fell at 4:30 p.m., Jan. 23, 1852.
One stone of about 13.6 kilograms weight.

YONOZU, Nishikambara, Echigo, Japan.
Fell at 4 p.m., July 14, 1837.
A stone of about 13.5 kilograms weight.

ZABORZIKA, Jitomir, Volhynia, Ukraine.
Fell April 11, 1818.
One stone of about 21 kilograms.

ZABRODJE, Vilna, Lithuania.
Fell 2 hours before sunset, Sept. 22, 1893.
One stone of about 3 kilograms fell through the roof of a house.

ZAVID, Zvornik, Bosnia, Yugoslavia.
Fell at 11:30 a.m., Aug. 1, 1897.
Four stones weighing 48 and 220 grams, and 2.5 and 90 kilograms.

ZEBRAK, Horovice (= Horowitz) Beraun, Bohemia.
Fell at 8 a.m., Oct. 14, 1824.
One stone of about 2 kilograms.

ZMENJ, Minsk, Russia.
Fell in August of 1858.
One stone of but 246 grams.

ZOMBA, Myasaland, British Central Africa.
Fell at 7:45 a.m., Jan. 25, 1899.
Several stones found scattered over an area of 3×9 miles, the largest weighing about 2.27 kilograms; total weight about 7.5 kilograms.

ZSADANY, Temes district, Rumania.
Fell between 3 and 4 p.m., March 31, 1875.
A shower of which but 9 small stones were recovered of a total weight of 552 grams.

II. STONY IRONS

Out of the score or more of stony irons variously classed as lodranites, mesosiderites, siderophyrs, and pallasites, but five were seen to fall. These are as follows:

BAREA, Logroño, Spain.
Fell July 4, 1842.
A mass of about 32 kilograms weight, belonging to the group of mesosiderites.

ESTHERVILLE, Emmet County, Iowa.
Fell at 5 p.m. on May 10, 1879.
A shower of several large and hundreds of small fragments totaling not less than 318.2 kilograms, the larger of which weighed some 68 and 153.2 kilograms. One of the most interesting of its class.

LODRAN, Multan, Punjab, India.
Fell at 2 p.m. on Oct. 1, 1868.
A stony iron of exceptional interest of which the original weight is not known and of which but 970 grams are preserved. It stands by itself in the class of *lodranites*.

MARJALAHTI, Viborg, Finland.
Fell at 10 p.m. on June 1, 1902.
One individual, a pallasite, weighing about 45 kilograms.

VERAMIN, Karand, Tehran, Persia.
Fell 3 hours before sunset in May, 1880.
An interesting mass of about 54 kilograms weight preserved in the palace of the Shah of Persia and from

which H. A. Ward secured the privilege of cutting away some 2 kilograms for other collections.

III. IRONS

Of the 350 known all-metal meteorites but 22 were seen to fall. These are as follows:

Avce, Isonzo Valley, Gorizia, Italy.
Fell at 8:45 a.m., March 31, 1908.
A mass of but 1,230 grams fell.

Bezerros, Pernambuco, Brazil.
Fell May 9, 1915.
A mass the original weight of which is given as 20 tons (18,181 kilograms).

Boguslavka, 220 km. north of Vladivostok, Siberia.
Fell at 11:47 a.m., Oct. 18, 1916.
Two masses of 57 and 199 kilograms respectively.

Braunau, Trutnov, Bohemia.
Fell at 3:45 a.m., July 14, 1847.
Two masses of 17 and 22 kilograms.

Cabin Creek, Johnson County, Arkansas.
Fell at 3 p.m., March 27, 1886.
A mass of 107 pounds (48.7 kilograms).

Charlotte, Dickson County, Tennessee.
Fell between 2 and 3 p.m., July 31 or Aug. 1, 1835.
A mass of about 4 kilograms.

Garhi Yasin, Shikarpur taluk, Sukkur dist., Bombay, India.
Fell at night time in January, 1917.
A small mass of but 380 grams.

Hraschina, Zagreb (-Agram) Croatia, Yugoslavia.
Fell at 6 p.m., May 26, 1751.
Two masses of 9 and 40 kilograms weight.

Mariaville, Rock County, Nebraska.
Fell at midnight on Oct. 16, 1898.
A small mass of but 340 grams weight. Perhaps doubtful.

MAZAPIL, Zacatecas, Mexico.
Fell at 9 p.m. on Nov. 27, 1885.
One of the most interesting falls on record on account of the details gathered. Fell during a star shower period and is thought possibly from Biela's Comet.

NEDAGOLLA, Vizagapatam district, Madras, India.
Fell at 7 p.m., Jan. 23, 1870.
A single mass of about 4½ kilograms.

N'GOUREMA, Jenne, Massina, French West Africa.
Fell June 15, 1900.
A mass of about 37.5 kilograms belongs to the rare group of brecciated octahedrites. (See Plate 42.)

N'Kandhla, Zululand, Natal South Africa.
Fell at 1:30 p.m., Aug. 1, 1912.
A mass of about 17.2 kilograms weight.

NORFOLK, Montgomery County, Virginia.
Fell in September of 1907.
A mass of 23 kilograms weight.

OKANO, Sasayama, Tamba, Japan.
Fell at 6:35 a.m., April 7, 1904.
A mass of 4,742 grams weight.

PITTS, Wilcox County, Georgia.
Fell at 9 a.m., April 20, 1921.
Four pieces classed as octahedrites with silicate inclusions and weighing about 4 kilograms.

QUESA, Enguera, Valencia, Spain.
Fell at 9 p.m., Aug. 1, 1898.
A mass of about 10.75 kilograms weight.

ROWTON, Wellington, Shropshire, England.
Fell at 3:45 p.m., April 20, 1876.
A mass of about 3.4 kilograms.

SAMELIA, Shahpura, Rajputana, India.
Fell at 5:30 p.m., May 20, 1921.
Three masses of total weight 2,461 grams.

TREYSA, Hesse, Germany.
Fell at 3:30 p.m., April 3, 1916.
A mass of 63 kilograms weight.

PLATE 42

1 2

(1) Front and (2) side views of an iron meteorite that fell at N'Gourema, Africa, on June 15, 1900. It is of unusual interest on account of its shape and being one of the 22 irons seen to fall

VICTORIA WEST, Cape Province, South Africa.
Fell 1860.
A mass of about 3 kilograms.
WINBURG, Orange Free State, South Africa.
Fell 1881.
A mass of about 50 kilograms.

PART II

GEMS AND GEM MINERALS

By

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PREFACE

In the preparation of this work, the writer has had the assistance and guidance of the Head Curator of the department, Dr. George P. Merrill, to whom is due the general plan and scope of the work. Doctor Merrill has also assisted in the preparation of certain portions of the text, the chapter on "Collections and Collectors" being wholly his. His assistance and interest I here gratefully acknowledge. It is my pleasure to also acknowledge the efficient help of Miss Margaret Moodey, scientific aid in the department, who has gone over the manuscript and supplied many of the interesting items embodied in the text.

A work of this kind must of necessity be somewhat of a compilation, and I have made free use of the works of other writers in this field. Many details were taken from the standard work of Max Bauer, *Edelsteinkunde*, and from the works of the eminent authority on gem stones, Dr. George F. Kunz. His valuable summaries on precious stones in *Mineral Resources of the United States* published by the U. S. Geological Survey, and also in *Mineral Industry*, have been freely consulted. Similarly the yearly reports of Douglas B. Sterrett, also appearing in *Mineral Resources*, have been frequently consulted. The bibliography given at the end of this work contains references to other books drawn upon for items of special interest.

W. F. F.

CHAPTER I

INTRODUCTION

It has been said that there is nothing more disenchanting to man than to be shown the springs and mechanism of any art. Here, then, is a fundamental difference between art and science, since, in the latter, to pry below the surface is not to be wearied but to be fascinated by the revealed wonders. Gems may be interesting for beauty alone, but to understand the sources of this beauty and know the romance of their history is to increase their enchantment manyfold. Even the business of their winning is not without its fascination.

Of all the wonders which nature has provided for the enjoyment of man, few hold a more prominent place in mythology and poetry than the gem stones. Originating in the natural objects which we know as minerals, they are found in the rocks and sands of favored places on our earth's surface, generally after laborious and highly speculative digging in the earth. After the miner has found them the skill of the artisan intensifies their beauty.

Man has sought these precious objects as far back as we know. Paleolithic man treasured the variegated pebbles and bright stones found along the stream banks, and in the earliest days of history gems were not only known and classified, but were the basis of a lively trade. Several thousand years before the birth of Christ, precious stones were cut and carved in Babylon. The Egyptians used them profusely, and in ancient China the origin of jade carving is lost in antiquity.

Nothing haphazard enters into the choice of a mineral for gem purposes. The stone must possess certain virtues to be "counted with the giants." Of these, beauty or splendor outranks all others. Without beauty a mineral may be useful but it will seldom be of value for ornamental purposes. Next, it should have durability, since it must resist the wear to which it may be subjected. Many minerals of beauty lack this important quality and hence are of little value as gems. Because men like to have that which others have not, rarity also is a valuable attribute and will, of course, affect the price and often the demand; but there are precious stones so rare as to be almost unknown, and for them the demand is limited to the connoisseur.

Each mineral has a definite and more or less simple chemical composition. If it has grown without interference it will have a form of its own by which it may be distinguished, and it furthermore possesses characteristic physical properties. Since each mineral is an entity, it is called a *mineral species*. Modern mineralogy now knows some fifteen hundred mineral species. Simplest of all are the *elements*, those units of matter indivisible by ordinary chemical means, of which all substances are made. These combine among themselves to form *compounds*. Both elements and compounds are found among the minerals and we may classify the most important as follows:

1. Elements: The elementary units of all substances, as the *diamond*, *gold*, and *platinum*.
2. Sulphides: Combinations of metals with sulphur, as *pyrite*, the sulphide of iron, and *galena*, the sulphide and common ore of lead.
3. Oxides: Combinations of metals with oxygen, as *quartz*, the oxide of silicon (silica), the commonest of minerals.
4. Carbonates: Combinations of metals with carbonic acid, as *calcite*, the common carbonate of calcium, and *malachite*, an important carbonate of copper.

5. Sulphates: Combinations of metals with sulphuric acid, as *gypsum*, the sulphate of calcium.
6. Phosphates: Combinations of metals with phosphoric acid, as *variscite*, a phosphate of aluminum, and *turquoise*, a phosphate of copper and aluminum.
7. Silicates: Combinations of metal with silica, as *cyanite*, a silicate of aluminum, and *beryl* (*emerald*), a silicate of aluminum and the rare element *beryllium*.
8. Hydrocarbons: Combinations of carbon with oxygen and hydrogen, as *amber* and *jet*.

Of the fifteen hundred mineral species, only about one hundred possess all of the attributes required in gems. The silicates furnish the greatest number, including such as beryl, topaz, tourmaline, and feldspar. From the point of view of value, however, the elements rank highest although there is but one gem in this class—the diamond. The oxides, too, are important, for here belong corundum (ruby and sapphire), quartz (amethyst, agate, etc.), and opal. Sulphides, carbonates, and sulphates are of small importance, while the phosphates yield only turquoise and variscite. Pearl, to be ranked with the diamond, ruby, and emerald in importance as a gem, is not, strictly speaking, a mineral, but is so intimately associated with precious stones as to deserve consideration here.

CHAPTER II

CRYSTALS AND THEIR GROWTH

Nearly every known mineral, when allowed to grow without external interference, crystallizes according to certain definite and well-known laws. It assumes the form of a solid bounded by flat planes which invariably bear a definite geometric relationship to each other. So constantly is this true that in a very large majority of cases a mineral can be recognized by the form assumed in the crystallizing process. Thus minerals like common salt (halite) and galena (the common ore of lead) will crystallize in the form of cubes; magnetite (the magnetic oxide of iron) in the form of octahedrons; quartz and beryls in the form of hexagonal prisms. The garnet has a form quite characteristic and not likely to be mistaken for that of any other mineral. The same is true of other species. (See Plate 43.)

As a further example of the striking regularity of crystals, mention may be made of the constancy of the angles between the faces, or bounding planes. Every crystal of a species has the same angle between the corresponding faces regardless of its size, origin, or the locality from which it comes. This fact offers an astounding illustration of the essential orderliness of nature.

The size of crystals varies greatly and depends, first, upon some inherent property of the substance, not well understood; and, secondly, upon the physical and chemical environment in which the crystal grows. Crystals may be so minute as to require the use of a microscope to detect the individual, or they may be many feet in length. Perhaps the largest crystals known are the huge spodumenes encountered in some of the mines of the Black Hills of South Dakota, which reach a length of forty feet. Beryl crystals with sharp faces may weigh a ton or more, while

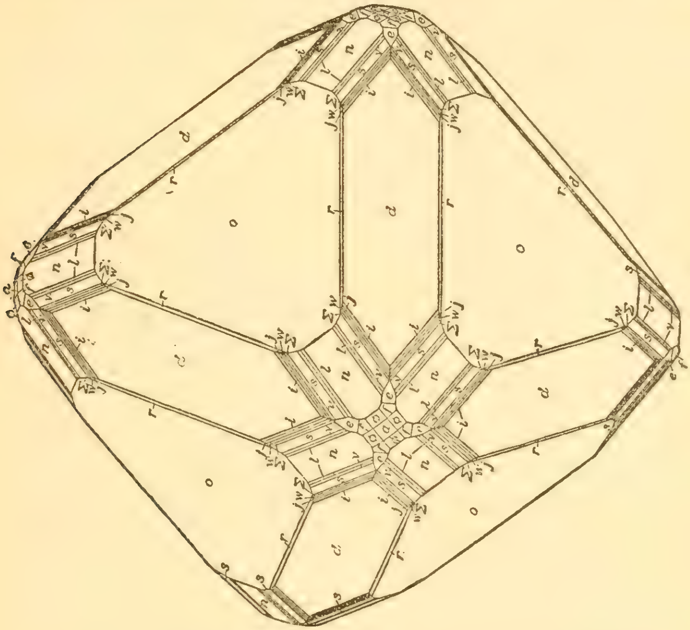


FIG. 8. Diagram of eglestonite crystal with 482 faces

single perfect crystals of gypsum from a cave in Mexico attain a maximum length of nine feet.

The shapes which crystals assume vary greatly, depending upon the number and relative size of the faces. The least number of possible faces, is, of course, four, making a tetrahedron. This form is not common but is so characteristic of the mineral tetrahedrite as to cause it to be known by that name. As an extreme case of a large number of faces, a rare mercury mineral, eglestonite (Fig. 8), from Texas, has 482 individual and distinct faces upon it. Many of the crystal forms fall, however, into simple and well-known geometrical solids, for example, the cube, octahedron, and four- and six-sided pyramids. There is in fact a strong tendency among minerals to assume the simplest forms possible, consistent with their own particular internal atomic arrangement. The largest faces developed are always those that have the simplest relation to each other.

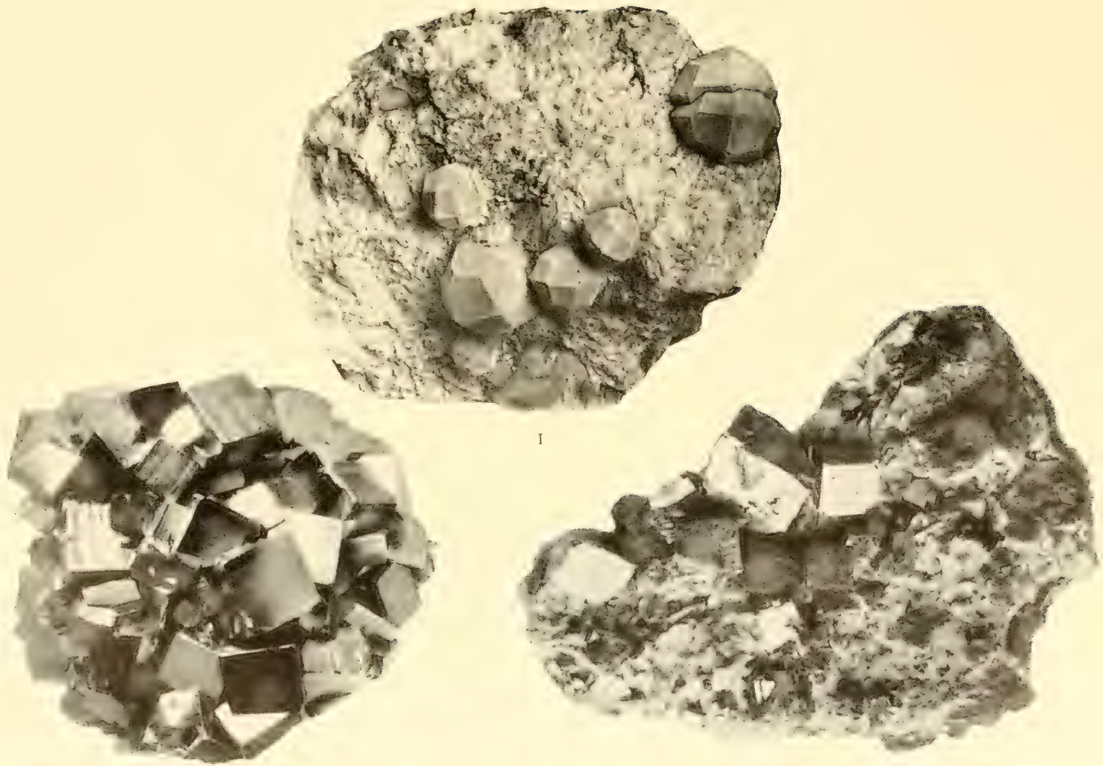
Usually a single substance may assume several forms: salt may grow as cubes or as octahedrons; calcite may be found as flat or steep rhombs, as prisms, or steep pyramidal forms. While these variations may at first sight appear to be incompatible with what has been said about the simplicity of crystal laws, a somewhat closer study will demonstrate the very near relationship between these forms, and the skilled crystallographer has no difficulty in properly grouping them.

In many, and indeed in the vast majority of cases, a mineral is prevented by interference from assuming a perfect crystal form, for example the quartz and feldspar in a granite, or the calcite in a marble. Nevertheless such faces as may develop are in strict accord with corresponding faces on the most perfectly formed individuals.

In the creation of her minerals, nature calls upon many of the giant forces at her command. For some, water is sufficient; others demand great heat and pressure. The turquoise requires much water and a little acid; the peridot needs the heat of lavas; while the creation of the diamond is one of nature's most jealously guarded secrets.

Of all the agents, water, the most active and useful of known substances, precedes in importance all others in the formation of minerals. It serves both as an essential chemical agent and as a means of transportation. It dissolves the substances found in the earth's crust, arranges them according to its fancy, and deposits them as minerals elsewhere. The water which carries on these

PLATE 43



1

2

3

Crystals of (1) garnet, (2) pyrite, and (3) galena, showing characteristic forms

PLATE 44

Quartz with inclusions of rutile. "Thetis hair stone"

Crystal of Quartz

activities springs from two sources: the heavens (meteoric waters), whence it descends as rain; and the bowels of the earth (magmatic waters), whence it ascends to the surface as the steam of volcanoes or as hot springs. The meteoric waters are of altogether predominant importance at or near the surface. To them must be ascribed the formation of such minerals as the turquoise, malachite, and others. The magmatic waters act deep in the earth and their handiwork is exposed only after long periods of erosion have removed the great thickness of overlying rock. They are directly connected with large reservoirs of molten rock from which come the lavas of our volcanoes. It is these waters that build up many of the deposits of precious and useful metals now found in our mines, and fashion for us the wondrous crystals of emerald, topaz, tourmaline, and other minerals for our finest gems.

There are, too, minerals which avoid water and are attracted only by the dry, molten rocks. Perhaps the diamond belongs to this group; the peridot certainly does since it forms only in lavas and similar rocks which seem to be devoid of water.

Nature offers few phenomena more remarkable than that manifested by a mineral in selecting out of the solutions brought to it by nature's processes those elements which are requisite to its growth, excluding the impurities, and building up its own characteristic form. Even if the process of crystal growth be for a time interrupted by a lack of material or through other causes, yet, when renewed, it will continue along the same lines as before. An interesting illustration of this is afforded in the conversion of a friable sandstone into a more compact form, quartzite, by a secondary deposition of silica between the sand grains in which each grain becomes the nucleus of a new crystal. Zonal growths due to periods of interruption, or inclosures of foreign material are thus explained.

The almost absolute purity, clearness, and beauty of some of these products of nature's laboratory offers food for thought. The most common illustration of this is ice, which is crystallized water and a true mineral. A better and more enduring illustration appears in the mineral quartz, an oxide of silicon. In form of clear hexagonal crystals with pyramidal terminations, quartz fills an important place in every collection. Because of its limpidity, it is often fashioned into crystal balls and other works of art.

As crystals grow by a process of accretion, it can readily be seen that there may develop a slight difference between the central or earlier and the outer or later formed portions, due to impurities in the solutions or to different forms of combination of some of the elements. Zonally built tourmalines offer the most striking illustrations of this feature (Plate 57). Of somewhat different character are the crystals of clear or smoky quartz capped by a later addition of amethyst.

The transparency of crystals is often diminished by impurities taken up during their growth. Few crystals escape these impurities; usually they are abundant. They may be gaseous, liquid, or solid. Some are visible to the unaided eye, others can be detected only by the use of the microscope. In minerals intended for gem purposes these inclusions become of serious importance for they constitute, in large part, the "flaws" of precious stones. The "carbons" of the diamond and the "silk" of the ruby and sapphire, which greatly detract from their value, illustrate such impurities. Liquid or gaseous inclusions are common but usually so minute that the unaided eye can not see them unless aggregated in great numbers. In some cases, however, the liquid body may reach a length of an inch or more and contain movable bubbles of gas.

Solid inclusions are frequently small crystals. When large and easily discernible with the naked eye, they may constitute the reason for the use of the mineral as a gem, as in the case of the "Thetis hair stone" (Plate 44) or in some varieties of cat's-eye, but more often they constitute flaws. Rutile, an oxide of titanium, often occurs in this manner and is particularly abundant in many rubies and sapphires.

In this day of the synthetic gem stone, these flaws often furnish the means of distinguishing the natural from the manufactured gem. The small crystallites of the natural mineral do not appear in the synthetic stones, while the gas bubbles of the latter are larger and more regular in shape than those of the natural material. Inclusions may also aid in determining the source of the mineral. There is, for instance, a difference in the arrangement of the rutile needles in the Siamese and the Ceylonese rubies. Emeralds from Siberia often contain small plates of mica, while those of Colombia may carry small masses of carbonaceous matter.

CHAPTER III

THE PROPERTIES OF MINERALS

All minerals share certain properties in common, though in unequal proportions, which must be known if one is to know minerals. In these properties lies the secret of the interest in minerals and of their economic importance as gems.

The beauty and splendor of gems depends in large measure upon *color* of which all known shades are found in minerals. The opaque stones must depend for their appeal on this alone, but when a deep rich color combines with perfect transparency, an object of unsurpassed beauty results and the stone takes its place as "of the finest water." "As blue as a sapphire" suggests the acme of freshness and purity in color.

The colors of minerals divide into two categories: those inherent in the mineral itself and known as essential colors, and those due to the presence of a pigmentary substance, and called nonessential. To the first class belong such colors as the blue and green of copper minerals, the pink of cobalt, the green, red, and brown of iron minerals. These colors are constant; they belong to the mineral itself, although they may vary somewhat in shade and nuance, and are not destroyed upon reducing the mineral to a powder.

The nonessential colors result from an extraneous pigment. They may be due to one of two causes; either to relatively large amounts of closely related substances that are themselves deeply colored (these are called isomorphous substances), or to minute quantities of a finely dispersed foreign material. In the case of the isomorphous substances a large amount of the pigmentary matter is usually necessary to impart a decided color to the mineral.

The pink tint imparted to calcite by the carbonate of cobalt, and the emerald-green of certain garnets, due to chromium, furnish examples.

In cases where the color results from finely dispersed foreign material, very minute amounts usually suffice to impart a deep hue to the mineral. In most cases, as in the sapphire, ruby, emerald, and amethyst, the coloring material is so tenuous that the amount and character can not be detected by ordinary chemical means, and the exact nature of these pigments remains therefore largely in dispute. According to Michel[1] the red of the ruby is due to minute amounts of chromium or to iron, while the pigmenting substance of the sapphire is quite unknown. To iron is ascribed the violet color of the amethyst.[2] The pigment of the diamond, which includes all colors and all shades and nuances, is so tenuous that no definite information can be given, though it seems quite probable that not only iron and other inorganic substances may be present, but also carbon compounds, especially hydrocarbons.

Michel lists the following elements and the colors they impart to minerals:

1. Chromium: green, violet, red, and yellow.
2. Titanium: violet, blue, yellow, red, and brown.
3. Iron: green, red, brown, yellow, blue, and black.
4. Manganese: red, rose, and violet.
5. Cobalt: blue and red.
6. Nickel: green.
7. Copper: red, blue, and green.
8. Uranium: greenish yellow, orange, and yellow.
9. Vanadium: yellow, red, and brown.
10. Molybdenum: yellow and red.

An interesting property connected with color is that of *pleochroism*, showing different colors or intensities of the same color when viewed through the crystal in different

[1] H. Michel. Die Künstlichen Edelsteine. Leipzig, 1926.

[2] Edw. F. Holden. *American Mineralogist*, Vol. 10, 203, 1925.

directions. The unequal absorption of the light rays as they pass through the crystal in these various directions causes this phenomenon. Often it manifests itself in a manner of striking beauty and becomes important in the cutting of the mineral for gem purposes. Thus, even in plates of the same thickness, a crystal of the common green tourmaline shows much darker when viewed in the direction of its vertical axis—which is generally the axis of greatest elongation—than when viewed across it. In the same manner the pink form of the mineral spodumene (kunzite) may be almost colorless when viewed across the prism and of a beautiful pink in other directions. Since most colored gem stones reveal this property to a greater or less degree, it must be seriously considered in the cutting of a stone. In one direction the color may be of pure tone, in another, it may be degraded or inferior. Strongly pleochroic stones may be cut to show a dual color pattern.

Many gems, especially the colorless ones, gain their beauty by their unusual and striking effects upon light. Most important of these effects is *refraction*. When a beam of light passes obliquely from one medium into another (as from air into water) it is usually bent at the surface separating the two. This is known as refraction. Because of this characteristic, a spoon in a glass of water appears bent, or a tank of water appears shallower than it really is. This effect depends upon the fact that the velocity of light differs in different substances. Light has, for instance, only three-fourths the velocity in water that it has in air. The ratio of the velocity in air to that in the substance is called the *index of refraction* of that substance and can be most conveniently measured by an instrument known as a refractometer. Each mineral possesses a characteristic index of refraction, and its exact value is commonly determined for the purpose of identifying gem stones. It can be roughly ascertained by visual inspection; those minerals with low index of refraction have a limpid, watery transparency, while those of high index possess a high luster and appear as though dipped in oil or grease.

It has just been stated that the extent of refraction varies with the different substances through which the light beam passes. It also depends upon the color of the light; blue rays being refracted more than yellow, and yellow more than red. Hence a beam of white light on passing through a stone becomes separated into the various colored rays. This separation is called *dispersion.* The degree to which this phenomenon takes place also varies with different substances. In fluorite, for instance, the dispersion is very slight and the separation not distinct, and can not be detected by the unaided eye. In the diamond, dispersion is marked and manifests itself in the bright-colored flashes of blue and red so noticeable in the gem. Titanite (sphene) also reveals marked dispersive powers and a properly cut stone is thickly studded with small colored flashes of light. Much of the brilliance of gem stones depends upon this property.

Cleavage offers another distinguishing characteristic of many minerals. It manifests itself in a tendency to break or split with smooth shining surfaces along definite and, for the same species, constant planes. This tendency is strong in calcite, which can be broken into numerous small rhombs, and so pronounced in mica as to permit it to be split up into sheets less than a thousandth of an inch in thickness. On the other hand minerals like quartz have no evident cleavage, but like glass, break with irregular surfaces. These planes of cleavage are manifestations of the orderly arrangement of the molecules in the crystal. Perpendicular to the plane of cleavage the distance between successive layers of molecules must be relatively large and hence explains the ease of separation. The cleavage must likewise be parallel to a face of the crystal since this too is determined by its molecular arrangement.

Cleavage may play an important role in the mineral industry, rendering a stone unfit for certain uses, where its development is pronounced, or assisting in the work of cutting, as in the case of the diamond. The cutting of the famous Cullinan diamond, the largest ever found, exemplifies this. As stated by Wodiska[3], the distinction of cutting this stone—a doubtful distinction in view of the responsibility involved—was conferred upon the house of Asscher and Company at Amsterdam. Using a diamond-cutting saw, the cutter first made an incision following the line of cleavage at the point where the stone was to be split. Before the operator were crystal models cleaved to represent the effect upon the diamond so far as possible. In the incision a specially made steel knife was inserted. At the first blow struck upon the back of the blade, the steel knife broke against the adamant. At the second blow, the diamond fell into two parts and divided along the line of cleavage exactly as the expert had planned.

A gem must have durability as one of its cardinal requisites and the *hardness* of a mineral becomes therefore an important attribute. The harder a stone the greater its value for gem purposes, other things being equal. In consideration of this property a "scale of hardness" has been devised, as follows:

1. Talc: Can be easily scratched by the thumb-nail.
2. Gypsum: Easily cut with a knife.
3. Calcite: Can be cut with a knife but less easily.
4. Fluorite: Can be cut with difficulty.
5. Apatite: Can be cut with difficulty.
6. Feldspar: Can be scratched but not cut.
7. Quartz: Can not be cut; will scratch glass.
8. Topaz: Will scratch quartz.
9. Sapphire: Will scratch topaz.
10. Diamond: Will scratch sapphire.

[3] A Book of Precious Stones, 1909, pp. 50-52.

This scale enjoys wide use to designate the hardness of both minerals and gems. In order to resist wear, gem minerals should have a hardness of at least 7.

The final property useful in determining a mineral is its *specific gravity*, which means the comparison of its weight with an equal volume of pure water. Diamond, for instance will weigh three and one half times as much as the same volume of water, hence we say the specific density of the diamond is 3.5. Each mineral has its own characteristic value. Amber has very nearly the same gravity as water, 1.0 to 1.1; platinum, on the other hand is very much heavier when pure, exceeding 20. One can gain some idea of the specific gravity of a mineral by its "heft"; if the mineral feels light it has a low value, if heavy a high value. The actual value is determined by weighing the mineral itself, and then the water that it displaces. The first weight divided by the second will represent the number of times the mineral is heavier than water and hence its specific gravity. This property is important in determining an unknown gem stone.

MYSTICAL PROPERTIES OF GEMS SINCE VERY EARLY TIMES

The physical properties of gems are a matter of scientific determination. Not so the talismanic, curative, and supernatural powers with which since very early times man has endowed them. Certain gems preserved him from incubi, vampires, and kindred terrors; others preserved him from the powers of sorcery or conferred the powers of witchcraft; by their aid he controlled the spirits of evil or was protected from their malign influence. With a suitable gem he could foretell the future, review the past, or conjure up pictures of events taking place at a distance. Protected by their mystic influences he feared neither plague nor poison, while his belief in the marvelous efficacy of their curative powers gave them a place among his most potent remedies.

The virtues of gems were diverse. Some procured the favor of the great; others rendered their possessor amiable, wise, strong, and brave; some protected him from fire, lightning, and tempests; others from danger and disease; some were preferred as talismans and charms; others were used as drugs, either alone or with electuaries, and with or without prayers, incantations, or other prescribed formulas.

Certain gems brought good or evil through the planetary influence of certain days. All yellow gems were appropriate for Sunday wear through the name-giver, the sun. On Monday, the moon day, all white stones except the diamond were to be worn. Tuesday, the day of Mars, claimed garnets, rubies, and all red stones. Wednesday demanded blue stones. Thor's day, or Thursday, required amethysts and other stones of a sanguine tint. Friday, the day of Venus, had for its gem the emerald. Saturn's day claimed the diamond.

A particular stone was potent for good during a particular month, and, under the proper astrological control was supposed to have a mystical influence over the twelve parts of the human anatomy. Such a gem was the more potent if the natal day of the wearer corresponded with its particular sign, and when worn as a birth or month stone was supposed to attract at all times propitious influences and avert malign effects. The more important stones, their zodiacal control, and most potent periods of influence are:

Stone	Zodiacal control	Period
Garnet	Aquarius	Jan. 21 to Feb. 21.
Amethyst	Pisces	Feb. 21 to Mar. 21.
Bloodstone	Aries	Mar. 21 to Apr. 20.
Sapphire	Taurus	Apr. 20 to May 21.
Agate	Gemini	May 21 to June 21.
Emerald	Cancer	June 21 to July 22.
Onyx	Leo	July 22 to Aug. 22.
Carnelian	Virgo	Aug. 22 to Sept. 22.

Stone	Zodiacal control	Period
Chrysolite	Libra	Sept. 22 to Oct. 23.
Aquamarine	Scorpio	Oct. 23 to Nov. 21.
Topaz	Sagittarius	Nov. 21 to Dec. 21.
Ruby	Capricorn	Dec. 21 to Jan. 21.

A closely related idea is found in the twelve stones which, according to the Jewish cabalists, when engraved each with an anagram of the name of God, were supposed to have a mystical power over, and a prophetical relation to the twelve angels. Thus:

Ruby	Malchediel
Topaz	Asmodel
Carbuncle	Ambriel
Emerald	Muriel
Sapphire	Herchel
Diamond	Humatiel
Jacinth	Zuriel
Agate	Barbiel
Amethyst	Adnachiel
Beryl	Humiel
Onyx	Gabriel
Jasper	Barchiel

These stones also had reference to the Twelve Tribes of Israel, the twelve parts of the human body, twelve hierarchies of devils, and so on. By their aid a system of prognostication was practiced, based upon the change of hue or brillancy of the stone, permitting the cabalist to foretell future events.

The twelve Apostles were represented symbolically by precious stones: Jasper, St. Peter; sapphire, St. Andrew; chalcedony, St. James; emerald, St. John; sardonyx, St. Philip; carnelian, St. Matthew; beryl, St. Thomas; chrysoprase, St. Thaddeus; topaz, St. James the Less; hyacinth, St. Simeon; amethyst, St. Matthias.

The superstitions connected with the twelve stones have persisted in one form or another from the times of the Magi to the present, and the belief in their virtues can still be traced in the wearing of "birth stones," as listed below:

BIRTH STONES

January.....Garnet (also hyacinth).
February....Amethyst (hyacinth and pearl occasionally used).
March......Bloodstone (also jasper).
April........Diamond (also sapphire).
May........Emerald (chalcedony, carnelian, and agate occasionally used).
June........Agate (chalcedony, turquoise, pearl, and cat's-eye occasionally used).
July........Ruby (carnelian, onyx, sardonyx, and turquoise occasionally used).
August......Sardonyx (carnelian, moonstone, alexandrite, and topaz occasionally used).
September...Sapphire (also chrysolite and sardonyx).
October......Opal (also beryl and aquamarine).
November...Topaz (also pearl).
December....Turquoise (ruby, bloodstone, and chrysoprase occasionally used).

In the *Sympathia Septem Metallorum ac Septem Selectorum Lapidum ad Planetas* appears a list of stones recorded as being in sympathy with the planets, and as such possessed of astrological and medicinal properties which, under the proper sign, rendered them of service to men. Thus—

[♄] Saturn....Turquoise, sapphire.
[♃] Jupiter....Carnelian, topaz, amethyst.
[♂] Mars.....Jasper, emerald.
[♀] Venus....Emerald, amethyst, topaz.
[☿] Mercury..Crystal, agate, emerald.
[☽] Moon.....Moonstone, topaz, and all white stones.
[☉] Sun......Diamond, ruby.

The Hindu propitiated hostile stars by the bestowal of gems. If the sun was hostile, a pure ruby; the moon, a good pearl; if *sani*, a star affecting to a powerful degree the destinies of men, a sapphire. He also averted the evil effects of adverse astral influences by wearing certain stones. If the sun was adverse, the cat's-eye; if the moon, the sapphire, and so on.

The mystic ascribed a certain significance both to the gem and to its various colors. For example, white was the emblem of light, purity, faith, innocence, joy, and life; worn by women it was emblematic of chastity; by the ruler, of humility and integrity. Red signified pure love and wisdom; in another sense it signified passion, love of evil, hatred, and so on. Blue was indicative of truth, constancy, and fidelity. Yellow in one sense was symbolical of marriage and faithfulness; in another sense of inconstancy, jealousy, and deceit. Green was the color of hope, especially that of immortality. Amethystine signified love, truth, passion, suffering, and hopefulness, and among the Rosicrucians was symbolical of the divine male sacrifice.

Stones of all sorts were engraved with the figure of a cockatrice, which, under the proper planetary influence, were preservatives against the evil eye. The names of Jesus, Mary, and Joseph were engraved on stones, chiefly amethyst, onyx, and bloodstone, which were worn as preventives of contagious diseases; the larger the stone, the greater its efficacy. Gems were also supposed to indicate the state of health of the donor or wearer. If the stone became dull, opaque, or colorless, it was thought to be significant of danger and death. In a similar manner they lost or changed color in contact with poisons.

Dreaming of gems was usually fraught with good, while seeing or handling them on the eve of a journey, or at certain phases of the moon, was regarded as auspicious.

With the progress of civilization such beliefs as these are slowly dying out and have for us chiefly an historical interest. They are touched upon later in this work in connection with the particular minerals to which they relate.[4]

MINERAL NAMES

No fixed rule for mineral nomenclature exists. In many instances the name given implies some definite property, as *pyrite* from the Greek word Πυριτης meaning fire, because it strikes fire against steel or other hard substances. Actinolite comes from ακτις, a ray, in allusion to the fibrous form of the mineral. Chlorite has come to us from a Greek word meaning green in allusion to its characteristic color, and steatite from στεατιτης, fat, in allusion to its greasy feel. From very early times it has also been a common custom to name minerals for individuals—"to create a progeny for the childless," as someone has expressed it; thus, *smithsonite* for James Smithson, the founder of the Smithsonian Institution. The terminal syllable *ite*, also of Greek origin, is now used almost universally, indicating a quality, constituent, or other characteristic. Many of the older names, as beryl, topaz, galena, etc., do not conform to this, or indeed to any apparent rule. They have come down to us from the Greeks and no suggested changes have thus far met with universal approval.

In many cases a distinctive physical property is emphasized in the name of the mineral, as azurite, for the azure-blue carbonate of copper; aquamarine for the sea-green variety of beryl; and rhodonite (*rhodos* "a rose") for the rose-red silicate of manganese. Names suggestive of fancied resemblances may be used, moonstone and sunstone for instance, while staurolite (*stauros* "a star") refers to its characteristic cross-shaped crystals. Localities have given rise to such names as turquoise, Turkey having been the channel for introduction of the mineral into Europe; amazonstone, because the material

[4] Those desiring further information should consult the bibliography on pp. 320-322 of this work and particularly G. F. Kunz's *Curious Lore of Precious Stones.*

was first noted as carved lip ornaments of the tribes of the Amazon; and vesuvianite, from the volcano Vesuvius. The chemical composition of the mineral is often reflected in its name, as manganite, an oxide of manganese; or magnesioferrite, an oxide of magnesia and iron.

While the names of persons are now often used in mineral nomenclature, they are only infrequently used for gems. This is due largely to the fact that personal names do not express the esthetic qualities that make gems desirable. Such personal names as have been introduced are not universally used with a few exceptions, such as hiddenite and kunzite, the former for Hidden, the American mineralogist, the latter for Geo. F. Kunz, the gem expert.

CHAPTER IV

KINDS AND OCCURRENCES OF GEM MINERALS

These gems have life in them: their colors speak,
Say what words fail of.

—George Eliot.

The Diamond

The diamond, generally conceded to take precedence over all other gems, has long been the most coveted of gem stones. In ancient times it was not common. Pliny says it "was long known to none but kings, and to but very few of them." At the present time, perhaps no other gem stone is so greatly in demand notwithstanding the fact that, with one or two exceptions, it commands the highest price of any on the market.

Knowledge of the diamond stretches far back into antiquity, how far no one knows. Ptolemy mentions a "diamond river" in India, and many ancient Sanscrit manuscripts treat of the diamond in considerable detail. It has also been asserted that the stone now known as the Koh-i-noor belonged to Karna, King of Anga, 5,000 years ago.

The remarkable physical characteristics of the diamond explain the esteem in which men hold it; no other mineral equals it in hardness; in range of color it includes nearly all the prismatic hues; its luster is peculiarly brilliant and is superior to that of any other gem. To its refractive and dispersive powers is due the flash of colors characteristic of the stone, the colorless or "white" specimens exhibiting this to the greatest degree. With the colorful beauties of the diamond before us it is indeed difficult to believe that graphite, that humble constituent of stove polish, lubricators, and "lead" for pencils, is the brother of the lordly diamond, yet it is true for both are pure carbon.

Commercially the "white" stones are most used. Indeed, few among the general public know that any others exist. A "black diamond" means only coal, and it must be acknowledged that in the rough state the resemblance is striking. But black diamonds can be had on the market and they are highly prized. In production the yellows and browns perhaps afford the greatest number of shades among the colored varieties. After these come the greens, though pure grass- and emerald-green stones are very rare, as are all the strongly colored varieties. Red stones of rich, deep tints and garnet, hyacinth, rose-red, peach-blossom, and lilac-colored stones occur but seldom. Blue diamonds are as rare as the red, and only occasionally are cinnamon-brown, black, milky, and opalescent stones met with. Diamonds without tint of any kind when flawless, are termed "first water." If they possess a steely-blue color they are called "blue white."

Color, brilliance, cut, and general perfection of a stone are all to be considered in estimating the value of a diamond. Of two stones, both flawless and of equal weight, one may be worth twice the other. Off-color or defective stones may sell at carat prices regardless of size, while the value of an ordinary good-water stone advances in an increasing ratio with its weight up to about twenty carats, beyond which no rule holds good. Exceptionally perfect stones have no fixed value, the price depending upon the purity and brilliance, and, of course, on the condition of the market.

Until the discovery of diamonds in Brazil in 1728, India was the leading producer of this precious stone, and yielded many of the famous diamonds of the world. The most celebrated of these, "the great diamond of history and romance," is the Koh-i-noor. Its early history is lost in the realms of fable and tradition, but it now rests, after recutting in modern fashion, among the great treasures of the British Crown. A second famous stone from this region is the Great Mogul, whose whereabouts is now not known. It was found sometime between 1630 and 1650 at the Kollur mine in the Golconda district, the producer of many great diamonds. Like the Koh-i-noor, it has left a trail of wars, rebellions, massacres, and murders in its wake; it has shared in the love affairs of the great and the financial vicissitudes of the humble. The region whence it came also produced the famous blue Hope diamond whose history has been so tragic as to make its name a synonym of disaster.

In India diamonds are found at three principal widely separated localities. The first is in southern India in the Madras Presidency, and embraces the districts of Kadapa, Ballari, Karnul, Kistna, and Godavari. This region includes the famous "Golconda" district, a name which belongs not to a mine but to the market where diamonds were cut and polished, bought and sold. The second locality is farther north and includes a large tract between the Mahanadi and Godavari rivers; it embraces Sambalpur and Waigarh, eighty miles southeast of Nagpur, as well as portions of the Province of Chutia Nagpur. The third region is in Bundelkhand, in central India, the principal working being near the city of Panna. The Indian diamonds were obtained in part from alluvial deposits and in part from a quartzose conglomerate; at Panna this conglomerate appears to be largely made up of fragments of an older sandstone, which, it has been suggested, may represent the original matrix. The yield of the Indian mines, once so large, is at present very small.

Borneo shares with India the distinction of having yielded many of the early diamonds and has produced at least one large stone, the Matan, a steel-blue gem, still uncut and weighing 376 carats. Diamond-bearing deposits are known in two districts, one at the eastern part of the island in the region of the Kapuas River, and the other in the southern part not far from the city of Bandjarmassin. The stones are found in the river gravels and are mined in primitive fashion by the natives. They sink pits, hauling out the gravel by hand in baskets. The clay is washed out by trampling and stirring with the feet. Finally the diamonds are concentrated in low, conical vessels by skillful washing. Borneo diamonds vary greatly in color, and the fine blue stones from the island are considered equal to any in the world. Gold, platinum, and fragments of sapphire are often found in the gravels with the diamonds.

In the State of Minas Geraes, near the present town of Diamantina, Brazil, the attention of the slave miners working in the gold diggings was often attracted by bright pebbles which they used as counters in their games of cards. They little guessed that one of these alone might buy their freedom. Eventually some of these stones found their way to Lisbon where the Dutch consul first recognized them as diamonds. The discovery led to eager search until today several extensive and widely separated areas yield the precious gems. Two important districts are in the State of Minas Geraes, one about the headwaters of the Rio Jequitinhonha, of which the town of Diamantina is the center; a second is at the headwaters of the Rio San Francisco, about the town of Bagagem. In the State of Bahia an extensive field is located about the town of Lencoes.

The diamonds are found on the top of the plateau, where the workings are called "prairie diggings," or in the valleys of the rivers where they are called "river diggings." The original home of the diamond, as near as can now be determined, is in a peculiar quartz rock called *itacolumite*, from which the gems have been separated by the action of weather and streams. The diamonds are washed from gravels much as gold is washed from similar deposits, and the stones carefully picked out by hand. Formerly, when slaves did the work—and these laborers found many of the famous diamonds of Brazil—it was the custom, as a means of encouraging honesty, to crown the lucky finder of a large stone with a wreath of flowers and lead him in procession to the manager where he was given a new suit of clothes, and—what was infinitely more precious to him—his freedom. The most famous diamond of Brazil, the Star of the South, a stone of 254 carats, was found by a negress, who, as a further reward for the exceptional value of her find, obtained a pension for life.

Before the discovery of the diamond in South Africa, Brazil furnished the bulk of the modern world's production of this gem. Although still yielding a considerable quantity, the Brazilian industry has greatly declined, due to the enormous production of the African mines, to the crude and unsystematic means of working the deposits, and to the fact that the most accessible fields have been largely worked out.

The story of how Daniel Jacobs trekked to the little settlement of Hopetown on the banks of the Orange River, in South Africa; how the children gathered the brightly colored pebbles of the kopjes and scattered them about the yard when their interest waned; how the good farmer's wife noticed a shining pebble without bothering to pick it up, is now well known. Upon hearing of the stone, a neighbor expressed a curiosity to see it, but the stone had been thrown into the yard and was only recovered after a search. This neighbor, having a vague idea that the stone might be valuable, put it into the hands of a traveling trader who offered to find out what it was. Eventually it reached the hands of Dr. Atherstone, at that time one of the foremost mineralogists of the colony. Without hesitation, he pronounced it a genuine diamond.

Kimberley Mine, Kimberley, South Africa, showing the pipe-like nature of the diamond bearing rock.
(Photo by G. F. Williams)

It weighed 21¼ carats and was at once purchased by the Governor of the colony. This discovery stimulated the search for other stones, but ten months passed before another was recognized, and it was not until the following year that more were found on the banks of the Vaal. Two years later a shepherd boy came upon a superb white stone of 83½ carats. He sold it for the fabulous price of five hundred sheep, ten oxen, and a horse. Later the Earl of Dudley bought it for £25,000, and thenceforth it bore the name, Star of South Africa.

With this find the diamond fever spread and the great diamond rush began. The next year saw new discoveries on many of the farms about the present city of Kimberley, first in the beds of the streams, later on the rocky kopjes scattered over the region. The later vicissitudes of the mines, the fortunes and misfortunes of the miners, their arguments and controversies, and later the consolidation of the small and often conflicting holdings into one great organization by Cecil Rhodes and his associates are now a matter of history and can be but briefly mentioned here.[1]

The South African diamond workings are of two kinds, river diggings and dry diggings. The river diggings are in the gravel of the Vaal River from Potchefstroom down to its junction with the Orange River, and along the latter as far as Hopetown, the principal workings being along the Vaal between Klip Drift and its junction with the Hart River. The dry diggings are chiefly in Griqualand-West, south of the Vaal River, on the border of the Orange Free State, about 640 miles northeast of Cape Town. There are here a number of limited areas approximately spherical or oval in form, with an average diameter of some 300 yards, the entire productive area being within a circle having a radius of about two miles (Plate 45). These mines were originally worked as individual claims, but they are now all consolidated in one gigantic

[1] The interested reader is referred to authoritative and comprehensive works like that of Mr. Gardner F. Williams (The Diamond Mines of South Africa), and M. DeLaunay (Les diamants du Cap, Paris, 1897).

monopoly, which practically controls the diamond output of the world. Some idea of the enormous output of the region may be gained from the statement that from 1867 to 1887 over 33,000,000 carats, or more than six and one-half tons of diamonds were taken out.

At the Kimberley mines the diamantiferous area is inclosed in a wall of nearly horizontal black carbonaceous shale. The upper portion of the deposit consists of a friable mass of pale yellow color, called the "yellow ground." Below the reach of atmospheric influences the rock is more firm and of a bluish-green color; it is called the "blue ground." This consists essentially of a serpentinous breccia inclosing fragments of carbonaceous shale, bronzite, diallage, garnet, magnetite, etc. The diamonds are distributed through the mass, often to the amount of four to six to the cubic yard. These areas are believed to be volcanic pipes and the occurrence of the diamonds is obviously connected with the igneous intrusion, either being formed by the action of heat upon the carbonaceous shales, or being brought up from underlying rocks.

The weight of diamonds in the blue ground is almost infinitesimally small. At the present time less than one carat of diamonds is recovered from each four loads (1,600 pounds) of ground. To recover such a small quantity of precious matter from so much that is valueless requires ingenious and highly efficient methods and machinery. In the early days a mine was a bewildering sight. Miles of cable ran across each individual claim in all directions, and each pit was worked by its owner according to individual vagaries. Today the mines are worked by the most modern of mining methods. The blue ground, when brought to the surface, is carried to level floors, exposed to the sun and rain, and harrowed to hasten the decomposition of the rock. The time consumed ranges from three to six months. The rock is then washed in machines especially designed for this purpose, the fine clay and lighter minerals removed, and the diamonds with the associated heavy but valueless material sent to the sorter, a highly ingenious machine in which the diamonds are passed over a pulsating table coated thickly with grease. It is a remarkable fact that the diamonds will adhere to the grease while the other minerals of the concentrate pass by.

Large diamonds are not uncommon in the South African fields. In fact stones of 100 carats have been found so frequently that they no longer occasion great excitement—except to the owners. When, however, one finds a gem the size of a fist and weighing 3,024 carats (almost two pounds), flawless and of the finest blue water, it requires but a small stretch of the imagination to believe in Sindbad's Vale of Diamonds. Such a stone was picked up by a manager of the Premier mine during a casual stroll of inspection. This huge gem became known as the Cullinan, and was more than three times larger than its nearest rival. It is reported that when King Edward VII saw it, he remarked as he held it to the light, "I should have kicked it aside as a lump of glass if I had seen it in the road." No exact estimate of its value has been attempted. Upon cutting, a task entrusted to only the most skilled diamond workers, it yielded two wondrous gems, one 516½ carats and the other 309 carats. Seven other fine stones, ranging in size from 92 to 4½ carats, were furnished by this monstrous crystal. The largest stone adorns the scepter of the British King, while two others are in the Queen's crown.

Until the discovery of the Cullinan, the Excelsior, found in 1893, was the largest known diamond. A native workman picked the stone from a load of dirt at the Jagersfontein mine in Orange Free State. Before cutting the Excelsior weighed 971 carats and has been described as resembling the blunt end of an icicle. Mark Twain in his *Following the Equator* refers to it in these words: "Some say it is as big as a piece of alum, others say it is as large as a bite of candy, but the best authorities agree that it is almost exactly the size of a chunk of ice." Failing to find a purchaser, this huge gem was cut into twenty-one stones, the largest weighing 68 carats.

A third large stone, called the Jubilee in honor of the diamond jubilee of Queen Victoria, came to light in the famous Jagersfontein mine in 1895. It weighed then 634 carats. The Imperial, a fourth famous stone was said to weigh 457 carats.

In the Belgian Congo and Portuguese Angola there is a wide stretch of diamantiferous country, approximately 150,000 square miles in extent. This is the area drained by the north-flowing tributaries of the Kasai and Sankuru rivers between longitudes 17° and 26°. The commercial diamond deposits are all found among the river or creek gravels, or in bench gravels above the level of the present water courses. The gravels vary considerably in their diamond content, some carrying but a fraction of a carat per cubic meter, others yielding as many as ten carats for the same amount of dirt. A large proportion of the stones are transparent and colorless; others are slightly tinted brown or yellow, and rarely the highly prized intense blues, greens, and reds occur. As yet no diamonds of unusual size have been reported from this field.

In 1908 diamonds were found in South West Africa, then a German colony, which rapidly became a producer of stones of excellent quality. Some ground was so rich as to yield two hundred carats per cubic yard. Stones have even been recovered from the sea bottom at Luderitz Bay. A further discovery occurred at Abomoso, Gold Coast, and new finds follow one another at frequent intervals throughout a wide area in central and southern Africa.

Within the last few years British Guiana has become an important producer. The gems occur in alluvial gravels from the Mazaruni, Putarang, and Potaro rivers. It is said that the natives, observing that certain pebbles

Trenches in decomposed diamond-bearing peridotite, Arkansas mine, Pike County, Arkansas. (After Miser and Ross, U. S. Geological Survey)

resisted wear much better than any others, first utilized these diamonds in making graters, implements used in the preparation of their food, made by thrusting sharp pebbles into wood. As is usually the case in alluvial fields, the yield of precious stones here is extremely variable, ranging from ½ to 16 carats per cubic yard.

In New South Wales and in Victoria, Australia, diamonds are recovered in small amounts in the gravels worked for tin and other metals.

North America was not in years past regarded as a diamond-producing area. Yet a number of our States have yielded the mineral, often in considerable quantity but as yet never sufficiently to make any impression upon the diamond market. Besides the localities concerning which there can no longer be question, there are a number of places from which they have been reported, but without the presentation of the necessary evidence. A wildly enthusiastic account of the finding of diamonds in Georgia was published some years ago[2] but the statements were never corroborated, and it may well be doubted that one was found as large as the egg of a guinea fowl. A reported diamond field in Arizona, which caused considerable excitment in the seventies, proved wholly fraudulent.

Most of the diamonds found in North America have been obtained from the mines of Arkansas, from the gold placers of the Piedmont region of the Carolinas and Georgia and of the western United States, especially California; and from glacial deposits in regions as widely separated as Wisconsin and Nova Scotia. Of these stones only those of Arkansas have been found in place, all others having been separated from their sources either by streams or glaciers. Those from placer deposits can not in most cases have traveled very far and the general neighborhood of their origin can be determined. The glacier-borne diamonds were carried from their parent ledges by the southerly traveling ice sheet and its floods.

[2] M. F. Stephenson. Geology and Mineralogy of Georgia. Atlanta, 1870.

The occurrence in Arkansas of a rock strongly resembling the mother rock of the South African diamonds has long been known to geologists (Plate 46), but it was not until 1906 that J. W. Huddleston found diamonds in an outcrop on his property on Prairie Creek near Murfreesboro. This discovery led to a systematic search which resulted in the finding of other outcrops of the rocks, some of which carried the precious mineral, and which have since been mined with more or less profit. The yield of diamonds has varied considerably, but it is stated[3] that by 1922 over 10,000 individual stones had been found, the largest of which weighs over 40 carats. Several finds have weighed about 20 carats and one fine golden stone of 18 carats is in the Roebling collection in the National Museum (Plate 47). Most of the diamonds from the Arkansas locality are white, brown, or yellow, and many of them of high grade.

An unusual occurrence of diamonds is furnished by the glacial drift of the Great Lakes region, particularly at various points in Wisconsin[4] (Plate 48). The first reported diamond, weighing fifteen carats, from this area was found in 1883, during the digging of a well at Eagle, near Waukesha, Wisconsin. Since then a number of stones, both large and small have come to light, some of them of very pure water. The occurrence leaves little doubt that they were brought south by the glaciers and it seems reasonable to suppose that somewhere in the region between the Great Lakes and Hudson Bay there lies a diamond-bearing deposit of some importance that awaits the lucky prospector.

In the course of sluicing operations for gold carried on in the gravels of the Sierra Nevada mountains of California many small diamonds have been washed out. The chief localities are in Amador, Butte, El Dorado, and Nevada Counties. The stones from these areas number over two

[3] Miser and Ross. *Economic Geology*, Vol. 17, 1922.

[4] Wm. H. Hobbs. *Jour. Geology*, Vol. 7, pp. 375-388, 1899.

PLATE 47

Uncut diamonds, Arkansas. Roebling Collection, National Museum. (Enlarged about 2 diameters)

hundred, and many more must have been crushed and lost in the milling operations employed to treat the firmly cemented gravels. The largest diamond reported came from French Corral in Nevada County and weighed 7¼ carats.[5]

About ten authentic occurrences have been reported in the counties of Burke, Rutherford, McDowell, and Cleveland, North Carolina. The earliest recorded find dates back to 1843—an octahedral crystal valued at the time at $100. All the stones from this region have come from the beds of streams in the course of gold washing. The largest weighed about 4½ carats. A small boy picked up this stone in a spring near Dysartville in McDowell County.

Virginia has produced but one diamond, for many years the largest found in North America, though now surpassed in size by a crystal from the Arkansas fields. This stone, christened the Dewey, was turned up in Manchester in 1855 by a laborer engaged in grading one of the streets. The Dewey weighed originally 24 carats and produced a 12-carat cut stone, which is, however, off-color and imperfect. Exact copies of the stone were made, one of which was deposited in the U. S. Mint at Philadelphia and later sent to the National Museum.

Prospectors working the creeks for gold in Morgan and Brown Counties, Indiana[6] have found a few small diamonds. The largest one reported weighed 3¾ carats. In all, eight diamonds have been positively identified and others are perhaps in the hands of local residents.

Peridotite rocks similar to those of Arkansas and South Africa are known in Elliott County, Kentucky, but exploitation of the ground for diamonds did not yield the hoped-for results. Similar rocks are known near St. Louis, Missouri, and Syracuse, New York.

[5] Geo. F. Kunz. Gems, Jewelers' Materials, and Ornamental Stones of California. *Bull. Calif. State Mining Bureau*, No. 37, pp. 44, 1905.

[6] Geo. F. Kunz. *Mineral Resources*, *U. S. Geol. Survey*, 1902, p. 814.

MYSTICAL PROPERTIES

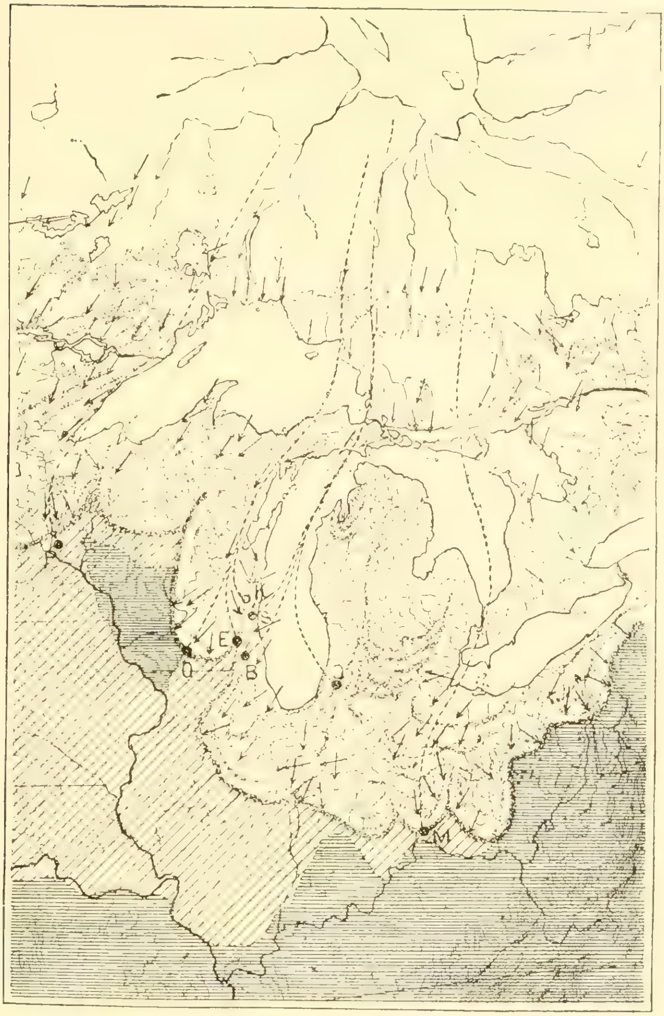
The diamond, being of all gems the purest, hardest, and most brilliant, was considered to be the most powerful in spiritual influences and was consecrated to all that was holy and heavenly. It was symbolical of constancy, purity, and innocence, and hence early used in betrothal rings. It softened anger, strengthened love, and was considered an infallible test of conjugal fidelity. To the ancients the diamond represented inexorable justice and unchangeable fate, hence the judges of Hades were described as having hearts and bosoms of adamant.

According to the Talmud, a certain gem, supposed to have been the diamond, worn in the girdle of the high priest, if brought in contact with an accused man, became dark and dim if the suspect was guilty; if innocent, the stone shone with increased brilliancy.

Pierre de Boniface, a fourteenth-century alchemist, taught that one of the virtues of the diamond was to render its wearer invisible and invincible. In this connection it may be mentioned that the Shah of Persia is the possessor of a diamond set in a scimitar which is believed to render him invincible as long as he has it by him. The Shah also has a five-pointed star of diamonds which is thought to make conspirators instantly confess their crimes when in its presence.

A diamond ring was given to Mary, Queen of Scots, by Ruthven, as a talisman against danger and poison. The queen also possessed two other diamonds—"one medicinable and against poison," the other "medicinable for the collicke."

The Hindus held that the diamond was masculine, feminine, or neuter according to its marking and appearance. The masculine kinds were considered the best and were useful in medicine; the feminine diamond was auspicious to women; but the neuter diamond was destructive of vigor and brought weakness and disappointment.



GLACIAL MAP OF THE GREAT LAKES REGION.

Driftless Areas. Older Drift. Newer Drift.
Moraines Glacial Striae. Track of Diamonds
Diamond Localities E, Eagle O. Oregon.
K, Kohlsville. D. Dowagiac. M. Milford. P, Plum Crk. B Burlington

After W. H. Hobbs, Journal of Geology, Vol. VII, 1899

The Burmese call the diamond and arsenic by the same name, *chein*, on the ground that they are both fatal poisons. This belief was not unknown in Europe, for we find the diamond listed as one of the poisons given to Sir Thomas Overbury when a prisoner in the Tower; while Benvenuto Cellini, the famous goldsmith, writing about 1560, relates how his life was preserved by the roguery of an apothecary, who, being employed to pulverize a diamond intended to be mixed in a salad for Cellini with the intention of poisoning him, substituted a beryl as cheaper, thus saving the life of Cellini.

Ruby, Sapphire, and Spinel

It is a curious thing that many of our precious minerals often have several guises so vastly different that we must distinguish them by different names. Thus, the ruby and sapphire are, despite their distinct appearance, but one and the same mineral—corundum—and the differences other than color are so infinitesimally small as to defy even modern science to detect. We do not know definitely as yet why the ruby is red or the sapphire blue, but we do know that their range in color is bound up in some mysterious way with the very minute amount of chromium and titanium contained in the mineral. Besides the red and blue, we have other less desirable green, violet, and yellow varieties known commercially under the names oriental emerald, oriental amethyst, and oriental topaz.

In hardness this mineral is exceeded only by the diamond, and as it takes a high polish it forms one of the most durable and desirable of gems. When cut *en cabochon*, some of the translucent varieties, owing to microscopic inclusions, show a chatoyance in the form of a six-rayed star or elongated oval, giving rise to the so-called *star* or *cat's-eye* ruby or sapphire.

Not all corundum is clear and brilliant—only a very small proportion is, in fact, sufficiently attractive for gem purposes—but the dull mineral, whose great hardness makes it suitable for abrasive purposes, is one of the agencies used in bringing out the hidden beauties of other gems.

Rubies flawless in character and of the purest red color seldom exceed three carats in weight; those exceeding ten carats are among the rarest of gems. Sapphires, on the other hand, are often of great size and weight. Some found in a paddy field at Pelmadula, Ceylon, weighed one and two pounds, and stones exceeding one hundred carats are well known. Sapphires are, on the whole, much more abundant and more widely distributed than rubies and are consequently cheaper.

Little is known of many of the world's largest rubies for they are jealously held by the rulers of the countries in which they have been found. Tavernier, an early traveler to India, reported one of fifty carats owned by the king of Vashapur, and valued it at six hundred thousand francs. The German Emperor, Rudolph II, and others are said to have possessed stones the size of a hen's egg. A reported enormous ruby from Burma weighing 1,184 carats is of doubtful authenticity, and the large gem given by Gustavus III of Sweden to Catherine the Great proved upon recent examination to be a fine red tourmaline.

Among the large sapphires is a stone of 951 carats belonging to the Kings of Ava. A fine uncut stone in the Jardin des Plantes at Paris weighs 132 carats, and there are many more in private hands.

For centuries the finest rubies, the pride of monarch and mogul, have come from Burma, whose rubies more nearly than those found elsewhere, approach the pigeon-blood color so desirable in gems of this class. Three distinct areas in Burma produce these stones, Mandalay, Mytkynia, and Mogok. Of these the last is by far the most important and the greatest ruby-producing tract in the world. The gems are formed originally in the limestone that underlies much of the region, as a result of the intense metamorphism of the rocks. Only in exceptional cases, however, does the mother rock pay for the working, and the gems come almost entirely from the soil which results from the decomposition of the limestone. The natives use primitive means for the extraction of the gems, methods that have been in vogue no doubt for centuries, but European companies working the deposits make use of modern machinery.

Rubies are found in Siam also, but they are darker and less desirable than the Burmese stones. The district of Battembong not far from the capital city of Bangkok, produces them, though this is a district much better known for its wonderful sapphires.

In Afghanistan, not far from the city of Kabul, a deposit of rubies was worked for many years by the Emir of the country. From this region has come a good ruby of 10½ carats. Farther north, beyond the Hindu Kusch Range and on the banks of the Oxus occur other deposits that have yielded many of the fine rubies of the Moguls, but which are now believed to be largely exhausted.

The occurrence of the sapphire in nature is similar to that of the ruby, and the two are very often found together. The ruby mines of Burma produce sapphire also, and in the fields of Siam both gems are associated. This latter locality yields the finest of sapphires, closely approaching the cornflower blue that is so highly prized in this gem. The most important district is Battembong already mentioned as producing the ruby. The alluvial material consists of clay and gravel, from which the gems, after washing, are picked by hand.

The sapphire ranks among the most important of the gems found in great variety in many parts of the island of Ceylon. Derived primarily from the very ancient rocks from which the action of the weather has released them, the gems are concentrated in gravels by swiftly running streams. The richest area for the precious stones lies in the southern part of the island, especially in the districts of Ratnapura, Balangoda, and Rackwana. The most primitive methods distinguish the mining of the gems and since the manner is so typical of many regions, it may well be described in some detail. The miner picks out what he considers a likely-looking place, frequently in the most haphazard manner, as surface indications are often missing. He sinks a small shaft or pit and lines it with vertical poles backed with branches of trees, sticks, or palm leaves to prevent the flow of mud (Plate 49). One man, working in the bottom of the pit, fills a bamboo basket with the gem-bearing material and deftly throws it upward where it is caught by the man at the surface. If the pit is deep a third man may be stationed on a transverse pole midway down. At the surface the miners wash the pay dirt in circular baskets in a near-by stream to get rid of the mud. The most expert of the miners then examines the clean gravel, by sweeping it toward him with the hand, bit by bit.

The Vale of Cashmere has yielded many good sapphires, although their color is somewhat lighter than that of the Siamese stones. A landslide first exposed these gems but later search showed them to be abundantly present in the detrital material in the valley below. Their blue color aroused the interest of the natives, who did not, however, realize their value, with the result that they used as flints for striking fire many fine gems, worth more than all their possessions. Many stones were brought to Simla and Delhi where they were first sold as blue quartz or amethyst.

Variously colored sapphires are recovered from the gem-bearing gravels near Anakie, Queensland, but they lack the rich colors so eagerly sought after, although many of them show a marked change of color when viewed in different directions, and make rather pleasing gems. Other localities in Australia yield sapphires of more or less excellence.

The most important sapphire-mining operations in

Singhalese sinking a shaft for sapphires, Palmadulla, Ceylon. (Photo by F. D. Adams)

Washing for sapphires. New Mines Sapphire Syndicate, Judith Basin County, Montana

Open cut. New Mines Sapphire Syndicate, Judith Basin County, Montana

North America are those of Fergus and Granite counties in Montana, where miners washing for gold in the gravel bars of the Missouri River first came upon loose gem stones. Later, fine sapphires were discovered in the mother rock at Yogo Gulch in Fergus County. The sapphire-bearing rock is a volcanic dike cutting across the limestone country rock of the neighborhood. This dike is recognizable on the surface only by a slight depression a foot or so below the general level of the ground, emphasized by the grasses and herbage which grow upon its soil in contrast to the barren limestone slopes. In the hollows and gulches the dike outcrop can be traced by a line of gopher and badger holes which mark its extent. No solid outcrops of the dike rock occur as it weathers to a soft clayey material. That is why gopher heapings mark the course of the dike, the undecomposed adjacent limestone being too hard for the animals to burrow in. The holes, indeed, proved the means of locating the dike when the claims were staked, and many of the finest stones obtained were picked up from the heapings made by these animals.[7]

The sapphires are scattered through this igneous rock. They range in size up to 4 or 5 carats. Rarely crystals of 8 to 10 carats are found. The color ranges from light blue to a rich corn-flower blue. These Montana stones make very beautiful gems; the best of them are unsurpassed, and hence are highly prized.

Near the surface the country rock, as noted, is weathered and somewhat resembles the blue earth of the South African diamond mines. From this earth the sapphires are easily washed out. As for the harder rock from the lower portions of the dike, exposure to the action of the weather for several months "slacks" (slakes) it, when it is easily washed to recover the gems. (Plate 50.)

A second type of deposits occurs in the form of placers along Dry Cottonwood Creek, about 16 miles north of

[7] W. H. Weed, *20th Ann. Rept., U. S. Geol. Survey*, Pt. iii, p. 455.

Anaconda. The original source of the sapphires here is unknown. The mineral occurs in rough crystals, as irregular masses, or as waterworn pebbles. They are much paler in color than the Yogo sapphires, the usual shades being deep and light aquamarine blue and yellowish green. Other shades include clear and smoky blue, light and dark topaz yellow, light and dark pink, and colorless. Rock Creek, in Granite County, about 15 miles southwest of Phillipsburg, affords another locality for placer sapphires. The stones found here are used chiefly for industrial purposes such as watch bearings, since but few of good gem quality are found.

A few small sapphires of a good cornflower blue have been found in the placer mines near Meadows Post Office, Washington County, Idaho. Most of the stones lack clarity but many show a cat's-eye effect when properly cut.

The Piedmont belt of North Carolina and Georgia contains many corundum deposits that have been exploited in the past as a source of common corundum for abrasive purposes. At the same time a few localities have yielded gems, chiefly rubies. At Corundum Hill, near Franklin, Macon County, small crystals or fragments turned up occasionally of sufficiently good color and clarity to yield small gems. The nearby Elijay Creek has produced some good ruby corundum and a peculiar brown or bronzy variety which shows a distinct star. Cowee Valley, Macon County, produced some small but very fine rubies; they were not, however, in the mother rock but in the gravels of the streams, associated with the beautiful rose-red garnet known as rhodolite. A few stones have come from many other localities throughout this region, rarely any of first quality, and in no case has mining yielded profitable results.

Mass production of artificial sapphires and rubies has caused no appreciable falling off in price of or demand for the genuine stone.

Gem dealers know another mineral, called spinel, which, though it differs from ruby and sapphire in chemical composition and other respects, so closely resembles the true ruby in color, luster, and hardness as to be confounded with it and often made to pass in trade for the more valuable species. The usual color is red, varying from light to dark in all shades, and it is often called *ruby spinel* or *balas ruby*. Stones of sapphire blue and even yellow and colorless specimens occur, but are less common. Gem stones of spinel are as a rule small, rarely exceeding ten carats, though large flawless stones of upward of 100 carats are known. The gem varieties come mostly from Burma and Ceylon, where they are obtained in the washing operations for the true ruby and sapphire.

Spinel and related minerals are not uncommon in many places in the United States, but as yet no gem stones have been found here. From a considerable area in southern New York and northern New Jersey have come abundant crystals of large size, many several pounds in weight, but they are all of dark shades and lack the necessary clarity for gem material, although very small ones are occasionally transparent. These spinels have their home in limestone rocks, where they are associated with corundum. The pegmatite dikes in North Carolina, especially at Spruce Pine, have produced some very large masses. A bright-blue variety, colored by cobalt, has been found in Maryland.

MYSTICAL PROPERTIES

Various members of the corundum species seem to have enjoyed in popular tradition all the virtues of which the people had knowledge. The ruby was said to be emblematic of love, a sovereign remedy and amulet against plague, poison, evil thoughts, and nightmare, and to divert the mind from sadness and sensuality.

The ruby enters the Chinese pharmacopoeia as an ingredient in the "five precious fragments," supposed to include ruby, topaz, emerald, sapphire, and hyacinth. The Hindu writers held that those rubies

> which are flawless and of approved color are auspicious, produce health, wealth, wisdom, and happiness. If flawed or off-colored they bring humiliation, loss of friends, liability to wounds, loss of wealth, and lightning stroke; are fatal to domestic animals, and are inimical to life, wealth, and fame. The man who treasures a ruby furnished with every perfection, and which when cast in a quantity of milk a hundred times its bulk, makes the white mass one entire sheet of red, or sends out a red flame, is as meritorious as the celebration of the *Aswamedha jajna*. Such a stone leads to wealth, success, happiness, and long life. (*Mani-Málá* of Tagore.)

The sapphire was considered emblematic of wisdom. If placed on the heart it bestows strength and energy. St. Jerome states that the sapphire procures royal favors, softens anger, frees people from enchantment, obtains release from captivity, and prevents evil and impure thoughts. Because of its extreme coldness it was thought to preserve the chastity of its wearer, hence especially suited for ecclesiastical rings.

The Emerald and Other Beryls

Here again we find one mineral, the beryl, covering a number of varieties chiefly distinguished by color. It includes the emerald (green), aquamarine (blue-green), morganite (pink), golden (yellow), and other shades not distinguished by gem or trade names.

In chemical composition beryl is essentially a silicate of alumina and beryllia (or glucina). There are also present in variable proportions minute quantities of other elements to which the color is due: chromium in the emerald, iron in the aquamarine, while the pink and colorless forms carry several per cent of the alkali metals, potassium, caesium, rubidium. Much of the esthetic beauty of the mineral lies in its remarkable limpidity, fine color, and the high polish it will assume. Finally its durability recommends it. All varieties crystallize habitually in

PLATE 51

1. Beryl crystal, Acworth, New Hampshire
2. Emerald crystal, Stony Point, North Carolina

the hexagonal system and the form shown in Plate 51 is characteristic.

Of all precious stones, none has enjoyed a longer vogue than the grass- to sea-green variety known as emerald. Babylon, the earliest known market for precious stones,[8] bought gems as long ago as 4000 B.C. and the emerald appears among the stones offered in that ancient time. The Egyptians also knew the stone well, obtaining their supply from the very ancient mines of the Zabara Mountains, in upper Egypt near the shores of the Red Sea, where evidences of the ancient workings are still prominent.

At Muzo and adjacent areas in Colombia, South America, emeralds of wondrous beauty have been obtained for centuries. The history of these mines is lost in antiquity; they had been worked, some of them even to exhaustion, before the Spaniards first set foot in the New World. The Spaniards obtained their first indication of the source of the mineral in 1537 when Gonzalo Jimenez de Quesada, conqueror of the interior of Colombia and founder of the city Bogota, entered the valley of Guacheta and received nine emeralds as a gift from the Indians; but a number of years passed, due no doubt to the difficulties of climate and the jungle and to the warlike character of the Indians, before the exact source was found and the mines actually became productive.

The deposits occur in the western foothills of the eastern branch of the Colombian Andes, a distance of about sixty miles from the city of Bogota, an intensely tropical region characterized by high humidity and excessive heat, with a rank jungle growth that quickly obscures the abandoned workings. It is sparsely inhabited by the decadent remnants of the once truculent Muzo Indians, who now live in squalor and poverty. The State controls the mines as a government monopoly.

The emeralds occur in pockets of calcite veins that traverse a black carbonaceous shale and limestone. Most

[8] Geo. F. Kunz, *Eng. Min. Jour. Press*, Feb. 29, 1925, p. 363.

crystals when taken from the matrix are clear but later develop cracks; some fall to pieces upon removal. This unfortunate characteristic detracts greatly from the value of the stones as gems. Bauer states that unflawed emeralds are among the rarest of gem stones and as a consequence command a price higher than the diamond or ruby. Indeed, so rarely is the emerald found perfect that the saying "an emerald without a flaw" has become proverbial.

North America cannot compete with the southern continent in the number and character of its emeralds, though it has produced some stones of fair grade. The only locality of importance is Stony Point in Alexander County, North Carolina, where true emeralds were discovered about 1875. Farmers found the earlier specimens in the unproductive gravelly soil resulting from the decomposition of the gneissoid country rock. Later excavations revealed the source of the gems in pockets in the gneiss lined with crystals of quartz and other minerals. A number of crystals of an emerald-green spodumene, a silicate of lithia and alumina, sometimes called *hiddenite* or *lithia emerald*, were also found. (See page 250.)

The Ural Mountains of Russia not far from the city of Ekaterinberg (now called Sverdlovsk) have produced emeralds in some abundance. In 1830 a peasant searching for balsam made the discovery in this region. In the roots of a tree overturned by the wind he found a number of fragments of emerald which were later sold in Ekaterinberg. The gem material occurs in a mica schist, for the most part as crystals either singly or aggregated in druses. Fully transparent and fine emerald-green stones are rare here as elsewhere. The usual find is pale, translucent, and badly checked. In size, however, they have reached extraordinary proportions; the largest found measured forty centimeters in length and twenty-five centimeters in diameter. The former Czar owned a mass of the mother rock containing a number of crystals ten to twelve centimeters long, and many fine crystals remain in the Mining Academy at Sverdlovsk. These large stones are not of gem quality, although it is said that many of the smaller ones equal those from Colombia.

An occurrence similar to the Russian is found in the Habachthal in the Salzburg Alps, from whence it is believed the Romans obtained many of their emeralds. These stones seldom reach an inch in size.

The large emeralds of the world, though often of greater value, have not contributed so much excitement to history as have the large diamonds, and much less is known about them, probably because the finest came from the Spanish colonies and found their way to the Spanish monarchs and to the Pope at Rome, and so never entered the trade. The ranking emerald of which we have record belongs to the cabinet of the Duke of Devonshire—an uncut crystal from Muzo, weighing eight ounces and eighteen pennyweights and measuring 2⅓ inches in length and two inches in diameter. It is of wonderful color and clarity although slightly marred by several flaws. The Hope gems included an emerald weighing six ounces, said to be even finer. At the shrine of Loreto, reputed to have once been the home of the Holy Virgin and to have been transported to Italy by angels, rests a group of crystals of exquisite green color in the white mother rock. Over 400 years ago Peruvian miners made an offering of this unusual specimen to the shrine. A flawless stone of marvelous beauty, weighing thirty carats, belonged to the former Czar of Russia, and there are others among the royal treasures of Europe and the Orient.

Many tales have come down to us of the great emeralds of Montezuma and of the other lords of southern Mexico, but so far as we now know the republic possesses no locality capable of producing stones of any real consequence. Possibly the objects and ornaments of jade dug up in many places in the State of Oaxaca and elsewhere have been mistaken for emeralds. The native kings prized jade highly. The two pieces presented to Cortez by Montezuma were considered worth two cart-loads of gold, and may well have led the Spaniards to believe that gems of such almost inestimable value could be nothing less than emeralds. Among the so-called emeralds of unusual character was the pyramid that stood before the throne of the Lord of Texcoco, a neighbor of Montezuma. This passed into the hands of Cortez, who sent it to the King of Spain. Unfortunately these gems of such high value seem to have disappeared and not a trace of ancient emerald has been found in all the broad land of Mexico.

A small mineral aggregate in the collections of the Instituto Geologico de Mexico, coming from the old gold-mining locality of Placer de San Domingo in the eastern part of the State of Chihuahua, carries true emerald. The matrix is calcite and the occurrence bears a striking resemblance to that of Colombia. These same calcite veins carry gold and are remarkable in that the precious metal is directly associated with pitchblende, the principal ore of radium.

To pass to another variety of beryl: that known as aquamarine owes its name, as may be readily imagined, to its exquisite limpid sea-green color, which, however, sometimes varies to bluish shades. This variety occurs much more commonly than emerald.

Russia boasts an abundant supply of good gems of aquamarine, in three provinces—the Urals, Altai, and about Nertchinsk in Transbaikalia. In the Urals the chief localities center about the village of Mursinka where the mother rock consists of a coarse-grained granite. This is unusually rich in cavities filled with a brown clay, and in these are found the beryls, often accompanied by topaz and smoky quartz. The crystals vary in color from wine- to greenish yellow, yellow-green, blue-green, and pale blue, and are often entirely clear and well formed, varying in size from exceedingly small ones to those several decimeters in length. Local farmers recovered most of the stones and often reaped a rich harvest of gems of many kinds. These simple folks became such experts as to astonish visiting mineralogists by their learned discussion of this branch of science.

The fame of the beryls of Altai rests rather on their great size than on their beauty, although sky-blue and blue-green stones of good grade are found. In the Nertchinsk District, Transbaikalia, two important localities called Adun-Tschelon and Borschtschowotschnoi produce aquamarines. The Adun-Tschelon stones occur in cavities in a topaz rock, or in the soil of the mountain slopes. The colors vary between pale sky-blue, green-blue, wine-yellow, or colorless. The aquamarines of the second locality attain greater beauty in color and limpidity, and may reach ten centimeters in length and five in diameter.

So many fine and beautiful gems have been found in Madagascar as to win it the title, "The Isle of Beryls." It possesses many very ancient rocks, in the dikes of which occur aquamarine and other beryls, tourmaline, topaz, amethyst, rock crystal and others. A number of localities in the district about the capital city of Antananarivo produce good gems in abundance in the much weathered mother rock and in the soil and water courses where the action of the streams has released them.

Besides the emerald and the aquamarine there occur several other types of beryl equally interesting but less frequently seen. A soft rose-pink variety first came to light in the gem mines of San Diego County, California, associated with pink and green tourmalines and other gem minerals. For many years no other locality produced this rare form, but later Madagascar yielded pink stones of an even more attractive shade.

A golden-yellow beryl, with a peculiar fluorescence due to a small content of uranium, became known in South

West Africa. It received the name *heliodor*, in allusion to the resemblance of its fire to the rays of the sun. The quantity of this material is limited and all of the finest gems are reported to have been secured by the former Emperor of Germany.

Beryls of the common and aquamarine type occur in the pegmatite veins of the Appalachian region of the eastern United States, particularly in Mitchell County, North Carolina; Haddam Neck in Connecticut; Oxford County, Maine; Coosa County, Alabama. Fine, almost sapphire-blue stones have been found at Royalston, Massachusetts, and on Mt. Antero in Colorado; and the beautiful pink examples of the caesium-bearing variety are found in San Diego County, California, as noted above.

One can not leave the subject of beryl without referring to the really magnificent crystals from Brazil. One found near the village of Marambaya, near Arassuahy on the Jequitinhonha River in the State of Minas Geraes, of a green to yellow-green color and weighing over 220 pounds, was so clear that it could be seen through from end to end. With great difficulty canoes transported it down the river to the coast whence it was sent to Idar in Germany and there cut up into gems. It was estimated that this single crystal would yield over 200,000 carats of aquamarine. The collection of the National Museum contains several fine crystals from Brazil; one, a golden beryl, clear and flawless, weighs over two pounds; another, of a light emerald-green, the so-called Brazilian emerald, also weighs over two pounds. The Field Museum in Chicago possesses several large, light-green emeralds from Bom Jesus dos Meiros, State of Bahia. These Brazilian beryls come chiefly from the State of Minas Geraes where they are associated with other gem minerals, tourmaline, topaz, euclase, and amethyst. They are found in the beds of streams or in the soil resulting from the decomposition of the gneissoid country rock.

Beryl of the usual opaque green and yellow type forms a common constituent of the pegmatites mined for mica and feldspar in the Appalachian region of the United States and to a less extent in the Rocky Mountain area. The mineral occurs in sharply outlined hexagonal prisms with commonly flat terminal planes and in all sizes up to several feet in diameter and tons in weight. These large forms are usually less perfect as crystals and are rarely extracted entire. A crystal with broken terminations but quite perfect prism outlines, in the National Museum, measures 20 by 22 by 30 inches and still larger ones are known. Heretofore, the common beryl has had value as mineral specimens only, but as a source of the metal beryllium, contemplated for use in aeroplane motors, it may become of importance.

MYSTICAL PROPERTIES

Beryls seem to have been endowed, traditionally, with well-nigh all the virtues. They were used, we are told, with incantations to foretell the future and review the past; were efficacious in detecting thieves and forewarning of death; and were supposed to have power over evil spirits that could be made to work the wearer's will by means of suitable incantations. They rendered their owner cheerful, preserved and increased conjugal love, and cured diseases of the throat and jaws and disorders of the head.

The variety emerald seemingly possessed even more gifts than the common beryl. It was considered emblematic of happiness. Worn as an amulet it preserved chastity, and betrayed or punished its violation by flying into pieces or losing color.

The Pearl

Pearls are not minerals in the mineralogist's definition of the term, but they belong in any general discussion of gems. Produced by certain shell-bearing animals, they consist of regularly layered shells of carbonate of lime and organic substances. Many mollusks form true pearls, but of these only a few meet the requirements of man. Those few are made only by mollusks possessing a shell with an inner lining of mother-of-pearl, that is, a lining with a fine iridescence. This same iridescence is imparted to the pearl, giving it the beauty desired in gems. When the common edible oyster develops concretionary forms, as it often does, while they are true pearls, they lack beauty and hence have no value.

These concretionary forms built up in the body of a mollusk seem to represent a defense mechanism on its part. The occasion for the formation may be either the intrusion of a foreign substance or the presence of small yellow particles from the oyster's own tissue. The intruders are small spherical larvae which die when they penetrate the animal's body and then suffer embalming forever in a cell which may be of exquisite beauty. First, the mollusk wraps this nucleus in a layer of organic substance corresponding to the outer coating of its own shell. Then comes a very thin layer of carbonate of lime and a third layer of an organic substance known as conchylin. These last two layers are repeated a great number of times. The mother-of-pearl luster results from the interference of light brought about by the reflection from these thin concentric layers of the shell, in the same manner that the brilliant colors are brought out on a soap bubble. The oyster builds its pearl in exactly the same manner that it builds or repairs its shell, and the quality and character of the pearl is much the same as that of the interior of the shell.

Of the numerous mollusks that yield pearls, only two species produce precious forms. These are the sea pearl mollusk, *Meleagrina margaritifera*, which inhabits the tropical seas, and the *Unios* of the fresh-water brooks and streams. The sea pearl mollusk surpasses the other both in quantity and quality of its product. It lives in banks on the coral sea bottoms at a depth of 6 to 9, or even 18 meters. Divers recover the mollusk. They may use modern diving apparatus in the pursuit of their dangerous occupation, but they usually scorn such aid.

The most ancient and famous of the pearl fisheries are found in the Persian Gulf, centering at the island of Bahrein. All pearling operations are in the hands of the Arabs, who carry on now much as they have for centuries. The divers descend to the bottom by means of diving stones attached to ropes. They can remain beneath the water from sixty to ninety seconds. The oysters are opened by means of a curved knife and the pearls carefully sought.

The pearls of the Persian Gulf are not as white as those of Ceylon. Many of them have a distinct yellow color, but pink, bluish, gray, and black pearls are sometimes found. Because of the small size of the mollusk the shell does not command a high price and the profits accruing from the diving operations depend almost wholly upon the value of the pearls recovered. In other districts, as the islands of the Pacific, the value of the shells recovered far exceeds that of the pearls, and the search for the latter is consequently incidental to the pursuit of the shell.

The Ceylon fisheries follow those of the Persian Gulf in importance. The mollusk of this region does not grow large either, seldom larger than the palm of the hand, in contrast to the eight or ten inches of the Pacific mollusk, and hence is valueless for its mother-of-pearl shell. The pearls, however, are of the purest white color and very highly prized. The chief fisheries occur in the Gulf of Manaar, an arm of the Indian Ocean separating Ceylon from India. Because of the great eagerness with which the gems are sought, the government imposes stringent restrictions to prevent the extinction of the pearl mollusk. From time to time, inspectors visit the different banks and when they find conditions propitious for valuable returns, the beds are thrown open for diving. The open season lasts usually six weeks at the most, and a depleted bank lies fallow for six or seven years before it is fished again. Diving operations duplicate pretty much the practice in the Persian Gulf. Small lots of the shells may be opened by hand but the usual procedure is to expose the mollusk to the heat of the sun, permit it to putrefy and the fleshy parts to be eaten by blue-bottle flies which gather in hordes, until only the pearls and shell remain. This residue is washed and repeatedly picked over until even the smallest of seed pearls is recovered.

Among the South Sea Islands the gathering of pearl shells forms one of the principal industries of the natives. The mollusks of this area, as noted above, grow to large size and are chiefly sought for their shell. Many localities produce comparatively few pearls; others have them in fair abundance and these add greatly to the value of the catch.

The diver of the South Sea Islands surpasses all others in skill, scorning diving apparatus and even the use of diving stones. Before plunging he sits for several minutes repeatedly inflating his lungs to the fullest capacity and slowly exhaling the air through his mouth. He then drops over the side feet first, descends a few feet, and without apparent effort turns over and swims to the bottom. He remains below usually less than a minute, but some of the more adept are able to stay for longer periods of time, three and four minutes having been reported in exceptional cases. At the end of the day's work the catch is opened and searched for pearls. Sometimes, though not often, one may be found, but the shells pay an adequate wage for the day's labor.

The pearl fisheries of Australia, Malay Archipelago, and other districts resemble the South Sea Island fisheries and likewise are worked largely for their shell.

North America has no pearl fisheries of importance, compared with those of the South Sea and Indian Ocean areas. But the coast of Venezuela produces them fairly abundantly. It was here that Columbus, on his third voyage, found the natives in possession of numerous pearls. Similarly the pearls of the Gulf of Panama aroused the interest of Balboa on his journey across to the Pacific. Many gems were sent to Spain during colonial days, but the industry is now carried on in a desultory manner.

Pearl-bearing mollusks are found at various places along the Pacific coast of Mexico and especially along the coast of Lower California. The pearls produced here are noted for the great variety of colors which they display, and many fine gems have been recovered. It was the custom for grateful fishers to give pearls to the Mission of Notre Dame de Loreto so that at one time the mission possessed a valuable collection. The industry centers about La Paz, capital of Lower California.

Pearls from the fresh-water clams or mussels of streams of the eastern United States are common.[9] Many of the Indian tribes, especially those of the Mississippi Valley, knew of these pearls. Their prehistoric mounds often contained gallons and even bushels of them. Many were of large size, and in quantity exceeded the richest collections of today, but long years of burial have damaged them beyond use, so that they have no value except to the archeologist. Extensive pearl-gathering began near Paterson, New Jersey, inspired by the discovery in a fresh-water mollusk from a nearby stream of a large pearl of handsome color which sold in New York for $1,500. The ensuing excitement called attention to the possibilities of fresh-water pearl fisheries, and the search has spread until nearly every State east of the Rocky Mountains has yielded more or less pearls. The most important areas are found among the tributaries of the Mississippi River.

The fresh-water pearls are noted for their great range of

[9] Although mollusks yielding precious pearls are spoken of as oysters they are not related to the edible oyster of our coasts, the name being due rather to a general resemblance to the oyster. The pearl-bearing mollusks belong to the family of the *Unios* and are usually referred to as the fresh-water mussels or the fresh-water clams.

color, varying from pure white through shades of pink; yellow to purple; copper-red; also green and brown. A large percentage of them are irregular in shape, the so-called *baroque* pearls. Their form sometimes imitates the wings, teeth, or heads of different animals. As a rule they rank lower in value than do the sea pearls, being in general less lustrous.

A considerable trade has sprung up along the California coast in the utilization of the shell of the large mollusk called *abalone*. The shell shows on its inner surface a fine iridescence in a wide range of colors. The portion used occurs chiefly as a protuberance which is cut out and sold under the name of abalone pearl. Occasionally a true pearl is found in the shell, but rarely are these of much value.

In this connection it may be pointed out that the thick shells of many of the larger mollusks, like the well-known conch shells are composed of variously colored layers, the innermost usually white and the next below colored. Advantage is taken of this, as with agates, by cutting through and partially removing the white layer, leaving figures or other ornamental forms standing in relief, to form shell cameos.

Pearls vary greatly in color and shape. Some of those from Ceylon have a faint rosy tint and a beautiful "orient" (luster). The Persian Gulf product often has a slightly yellow tint, while Venezuela and Panama pearls are of a fine golden color, with much luster. From Australia come pearls of a pure, waxy white, with a fine silvery sheen, as well as occasional golden-yellow ones of excellent color. Black pearls are rarer, and greenish-black ones are the most highly prized of the colored varieties. The terms used in designating their shapes usually explain themselves —round, pear-shaped, drop-shaped, petal, and others. Baroque is the term applied to the irregular forms; seed pearls are the small round forms, while dust pearls are most minute and have little value.

Its composition of carbonate of lime and organic matter renders pearl quite soft, having a hardness of but 4. In consequence the gem requires care to prevent undue wear at the surface and insure the retention of its pearly luster. Acids easily affect pearl and hence the acid exudations from the skin may be injurious. Undue exposure to sunlight can injure it.

When stored in a dry place for a considerable length of time they may slowly lose their luster, due to loss of water from the conchylin layers, but if carefully wrapped in clean linen and kept moist with a few thicknesses of moist absorbent paper, this can be very largely prevented. With reasonable care, however, the "life" of a pearl may well exceed one hundred years.

In olden days men thought that the pearl sprang from celestial dew. Early in the morning, so they believed, at a certain season of the year, the shell fish rose from the sea bottom to draw in the air and drink the dew drops. Once within they crystallized into pearls. The quality of the gems varied according to the lucidity or muddiness of the air taken in. It is said that this poetic conception still holds in Arabia, and there they ascribe the scarcity of pearls during some years to a paucity of dew.

CULTURE PEARLS

In the formation of the pearl man has conquered one of nature's secrets but has not yet found it possible to dispense with the services of the humble mollusk. We have seen that the pearl begins in the intrusion of some foreign body into the mantle of the animal, which, as a protective measure the animal surrounds and thus forms the pearl. Man takes advantage of this peculiarity of the animal and artfully introduces the irritating stranger. The operation requires extreme care for it is not sufficient to insert the nucleus alone; some of the pearl-forming cells must be introduced as well, so that the entire process partakes somewhat of the nature of a surgical operation.

In the culture of the mollusk for its pearls, divers first gather the young from the sea bottom, to be kept in containers until three years old. A number are sacrificed to yield the cells for the pearl sac. Into others, chosen from individuals that produce the best mother-of-pearl, the nucleus and pearl cells are introduced. These are then placed in numbered wire containers and suspended from bamboo poles on floats. For seven years the oyster is carefully watched over, both the mollusks and the containers cleaned from time to time, and the groups moved from place to place whenever necessary to avoid rapid temperature changes or unhealthy water conditions.

The pearls so produced have the outward appearance of "wild" ones, and the expert may have difficulty in detecting the difference. In general they have a somewhat higher specific gravity but this cannot always be relied on to distinguish them. If the pearl is drilled for stringing, the central nucleus can often be detected with the aid of a magnifying glass.

Naturally enough, culture pearls, because of the difficulty and expense of their production, are quite expensive, but they bring considerably less on the market than the "wild" pearls.

Quartz

Few substances occur under a greater variety of forms and colors than the oxide of silicon commonly known as quartz. It forms the prevailing constituent of most soils and of the beaches along the seacoast, and abounds in the rocks of the earth's crust. Because of its hardness, lack of cleavage, and insolubility, it holds its own to the last under all normal conditions of weathering. In its primary form it occurs massive, in veins and cavities, usually colorless or white, and readily recognizable. Its crystals show six sides with acute pyramidal terminations,

Beads of citrine and rose quartz. Isaac Lea Collection, National Museum

varying in size from microscopic needles to masses a foot or more in diameter. Quartz varies in color and diaphaneity. Often beautifully transparent and colorless as glass, it is then popularly known as *rock crystal*. Violet colors give rise to the variety *amethyst*, one of the most beautiful of gem stones; *citrine quartz* or *cairngorm* is of a peculiar smoky yellow tint very much like topaz; *milky* and *smoky* forms are readily recognizable by their designations. A delicately rose-tinted, massive variety is popular under the name *rose quartz*. The mineral reveals one peculiar trait; while the colorless, milky, citrine, smoky, and amethystine varieties may all occur in good crystal form, the pink and rose-tinted varieties are rarely if ever found except massive. *Sagenite* is a clear, colorless, transparent variety pierced by numerous minute crystals of rutile, chlorite, byssolite, goethite, or tourmaline. It is sometimes known under the fanciful name of *flèches d'amour* (arrows of love). (Plate 44.)

Quartz of the clear, colorless type occurs in association with the pegmatite veins of the eastern United States and the Rocky Mountains. Beautifully clear examples of crystallization have for many years been known from the Hot Springs region of Arkansas, where the mineral occurs as a secondary product in clefts and crevices in sandstone. This, indeed, forms one of the noted regions of the world for crystal groups. Its occurrence in small, very perfect, and highly lustrous crystals, rarely over a centimeter in diameter, in cavities of the limestones of Herkimer County, New York, furnishes a peculiarly interesting phase of the mineral. The natural crystals are sometimes perforated and strung as beads without further preparation, and as such prove very effective as well as unique. So great is their brilliance that they are commonly called "Herkimer diamonds."

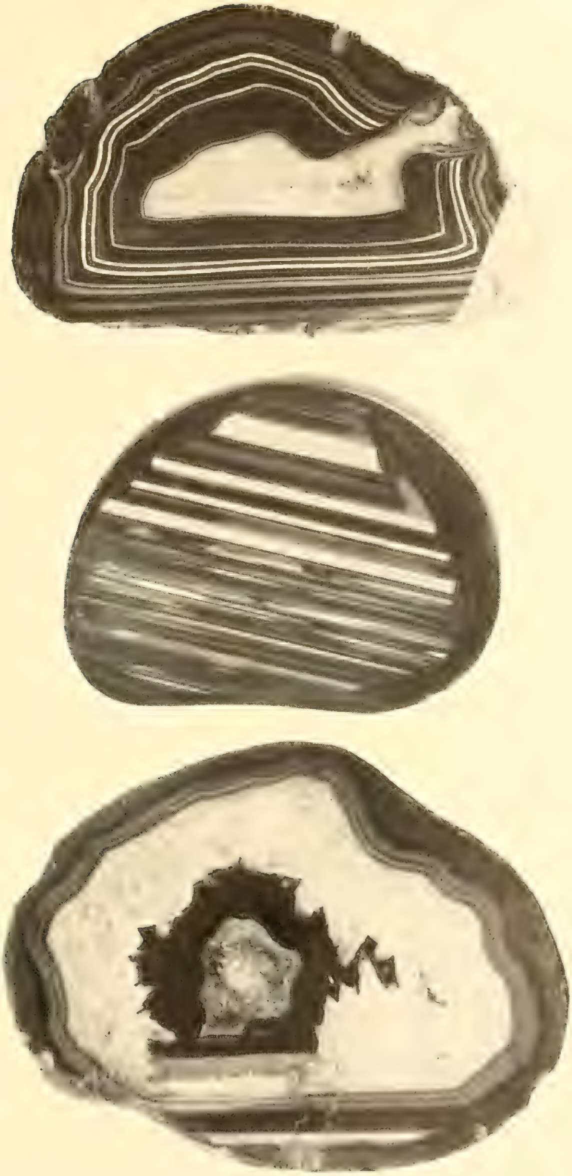
Quartz is the most common gangue mineral of ores of the precious metals. Mines in Placerville, Eldorado County, California, have at times yielded large and beautifully clear crystals, and in an ancient gold-bearing river channel in Calaveras County a quantity of enormous crystals were found embedded in the old gravel. The American Museum of Natural History has a crystal weighing 346 pounds; the National Museum has another of 309 pounds. These lack clarity and transparency, however.

Brazil, especially the states of Minas Geraes, Sao Paulo, and Goyaz, produces very important quantities of clear crystal quartz as well as of other varieties. Much of the quartz used for spectacle lenses and other technical purposes comes from that country.

Of other foreign localities mention should be made of the Swiss Alps where both clear and smoky crystals occur in open cavities. One such druse yielded about 20,000 pounds of good crystals. Lately Madagascar has produced much good rock crystal, a large part of the yield going into the manufacture of beads.

The violet quartz commonly known as amethyst varies in color from the palest shades to a deep purple. Often the color is not homogeneously distributed but is clouded and flecked through the stone. The clear and transparent varieties prove suitable for gem purposes, deeply colored stones coming first in popular estimation, although some of the paler tints are used. Mineralogists believe the color of amethysts to be due to finely dispersed iron compounds. Careful heating will cause a stone to assume a yellow color and ultimately become colorless; heated to the yellow stage it resembles the natural citrine quartz and many of the stones sold as the latter gem are obtained in this manner.

Amethystine quartz occurs commonly in the clefts and cracks of granitic and gneissic rocks; also in the steam cavities of old lava flows of the type called melaphyr. In this latter occurrence the crystals are often associated with agate, filling the open central space of the nodule. Yellowstone National Park has in years past yielded fine



Characteristic forms of agate

specimens of this type, but Rio Grande do Sul, Brazil, and the adjacent area in Uruguay are the world's most noted localities. In the ancient volcanic rocks of this region agate and amethyst line or completely fill the steam cavities. The quartz of this region comes unusually deep in color and of the finest gem quality.

This district produced a single geode surpassing in size and elegance anything of the kind previously known. It measured about 33 feet in length, 16.5 feet in width, and 10 feet in height, and had an estimated weight of 70,000 pounds. It was completely lined with richly colored amethyst crystals, many of them as large as a man's fist, with faces brilliant and lustrous as though polished by a lapidary. This geode was removed in sections and many of the crystals cut into gems, but a number of sections are now preserved in museums, including a 400-pound mass in the National Museum.

Very famous for its amethysts is the region about Mursinka, in the Urals, a district which, as we have already seen, abounds in aquamarine and topaz. Though many of the stones produced are light in color, abundant dark specimens with the pleasing property of changing to a deep cherry red in artificial light are found.

Amethystine quartz has a wide distribution in the eastern United States but nowhere does it occur in quantity sufficient to afford a stable industry. The soil resulting from the disintegration of the granitic rocks has yielded a large part of the material, and mining, if such it can be called, is confined to shallow surface workings. The crystals as found are almost invariably scarred and broken, though sometimes of a beautiful color. Providence township, Delaware County, and Chester County, Pennsylvania; Haywood County, North Carolina; and Rabun County, Georgia, have produced stones. Amethyst Harbor on the shores of Lake Superior has yielded very large crystals, though not of good gem quality.

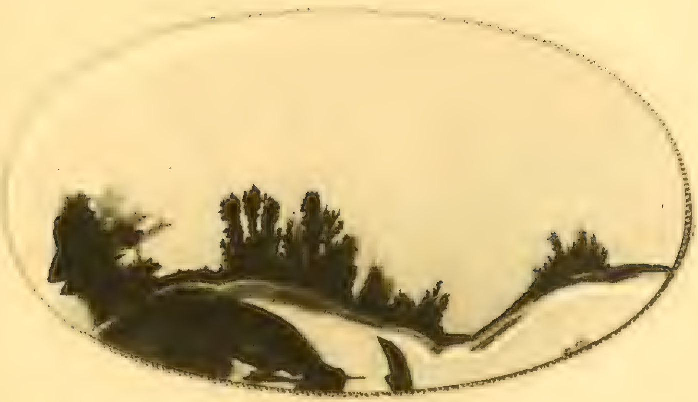
Amethyst occurs in a manner of interest to the mineralogist in the great silver mines of Guanajuato, Mexico. The mines about La Luz yield frequently large slabs of small but brilliantly colored crystals.

Quartz in its several varieties finds use both as a gem stone and for cutting into small ornaments, a work done by Orientals, and also by the Germans. The crystal ball of the astrologer supplies a favorite form. The largest ball known is at present in the National Museum, and measures 12⅞ inches in diameter and 107 pounds in weight. Absolutely clear and flawless, its value runs into many thousands of dollars. The massive rose variety furnishes a favorite medium for the quartz cutter, who often determines his design by the size and shape of the block. Beads, earrings, and pendants from quartz of various shades form one of the most satisfactory of the less expensive kinds of jewelry. (Plate 52.)

Chalcedony includes a very dense microcrystalline type of quartz known under a great variety of names. Most familiar, perhaps, is agate, a banded variety formed in the cavities of old lavas, the hearts of silicified logs, and other places, and owing its beauty to the concentric bands of deposition of infinite diversity. How banded agate forms still puzzles the scientist. Superficially it might appear that the duct in the upper right of Figure 1 on Plate 53 constituted an open channel through which the silica-bearing solution filtered in. But the duct could not have remained open throughout the filling process. Another possible explanation would have the cavity filled at one time with colloidal silica, gradually deposited in concentric coats as concentration of the solution through evaporation took place. The natural colors, it should be said, are gray or white, rarely red. The deep smoky brown, customary in commercial agate, and the green, blue, and other colors are for the most part artificially produced. The true onyx represents a variety of agate with nearly straight bands. The name comes from the Latin *oniscus*, in allusion to

PLATE 54

Landscape or "Moss" agates, Montana. Isaac Lea Collection, National Museum. (Slightly enlarged)



its resemblance both in banding and translucency to the nail on the human hand.

Although widespread in their occurrence, the chief commercial sources of agate today are the Province of Rio Grande do Sul in Brazil and the adjacent portion of Uruguay. The agate-bearing area, about 100 miles in length, extending from Porto Allegre in Brazil to Salta in Uruguay lies on an ancient volcanic flow of the type known as melaphyr. In the steam cavities of this rock the agate has formed. Much of the rock has weathered to a red or brown clayey soil. The rain constantly acts to remove this soil, leaving the agates upon the surface or in the streams and brooks of the region. Bluish gray predominates in the natural coloring of these agates, but they lend themselves readily to artificial coloring. Dense-black, bright-green, and red layers occur but rarely.

When nature desires to produce a unique type of agate she permeates the silica with manganese or iron compounds, giving rise to moss- and treelike forms, or islands in a miniature ocean (Plate 54), so-called *moss* or *landscape* agate. The chief American sources are Montana and Wyoming. Montana supplies much of the moss agate cut for jewelry from pebbles and cobbles found along the Yellowstone River and its tributaries and from the mesas and buttes for many miles away from the river. Where these agates developed originally no one knows. They occur in rounded cobbles, covered sometimes with a chalklike but hard coating of silica. In Laramie County, Wyoming, moss agate occurs in an irregularly shaped vein varying from less than one inch to nearly two feet in thickness, cutting nearly vertically across limestones of Carboniferous age. This is a clouded, more opaque form than the Montana agates.

The great variety of shades and colors presented by the chalcedonies make them admirable material for the smaller works of art, pendants, watch fobs, and similar trinkets. Color generally determines varietal names. *Bloodstone* is nearly black with blood-red spots and streaks; *carnelian* uniformly red; *prase* dull, leek green; and *jasper*, the most comprehensive term of all, includes the opaque red, yellow, and brown of all shades. Variously colored jaspers from the silicified logs of the so-called Fossil Forest of Arizona have been formed into objects of great beauty, some of which appear in Plates 55, 68, and 71.

Chrysoprase, a chalcedony colored light green by the oxide of nickel, has proved a favorite stone for gems since ancient times, though found in only a few places. Much of the material sold under this name has received its color artifically. Venice Hill, in the vicinity of Visalia, Tulare County, California, has yielded chrysoprase of unsurpassed quality. It forms small veins two-thirds of an inch thick in a jasper rock, and with it often occurs a similarly green opal called chrysopal. The deposits, extensively worked in the past, appear to be very nearly exhausted.

Although quartz is so widespread as a mineral, North America possesses no regular commercial source of supply for any of the varieties mentioned, though in years past very many agates were found on the lake shores of the Upper Peninsula of Michigan, where they weathered out of the trap rocks. The important gem-cutting industry of Oberstein-Idar in Germany owed its initiation to a supply of agates furnished by local trap sheets, now, however, exhausted. The material now sold on the market comes largely from Brazil and is cut in Germany or Japan. A variety found in California is cut and sold under the name *California moonstone*, a term as misleading as most of the trade names.

MYSTICAL PROPERTIES

The numerous varieties of silica described above have, in one form or another, been credited with an amost endless number of qualities and virtues. Mystics, astrologers, and diviners still use quartz balls to foretell the future, review the past, and conjure up distant scenes.

Amethyst is an emblem of sincerity. As an amulet it dispelled sleep, sharpened the intellect, prevented intoxication, gave victory to soldiers, protected its wearer from sorcery, lost its color in contact with and was an antidote for all poisons. If the name of the moon or sun be engraved on it and it be hung about the neck from the hair of a baboon or the feathers of a swallow, it is a charm against witchcraft.

Agate symbolizes health and wealth. An enemy to all venomous things, it assuages thirst when held in the mouth, gives victory to its wearer, repels storms, sharpens the sight, preserves and increases strength, and renders its wearer gracious and eloquent.

Bloodstone stands for wisdom, firmness, and courage, while carnelian, according to ancient authorities, cured all wounds made by iron, preserved the strength, prevented hoarseness, and cleared the voice. It also cheered the soul, banished fear and enchantments, and preserved harmony.

As the Greek legend has it, onyx originated when Cupid cut the nails of the sleeping Venus with his arrows; falling into the Indus, they were transformed into onyx. The belief that this stone caused nightmare and strife held wide sway, based on the assumption, as given by Beononi, that "in the onyx is a demon imprisoned in the stone who wakes only of a night, causing terror and disturbance to sleepers who wear it."

Sardonyx typified conjugal bliss. It rendered its possessor virtuous, cheerful, and agreeable.

The Opal

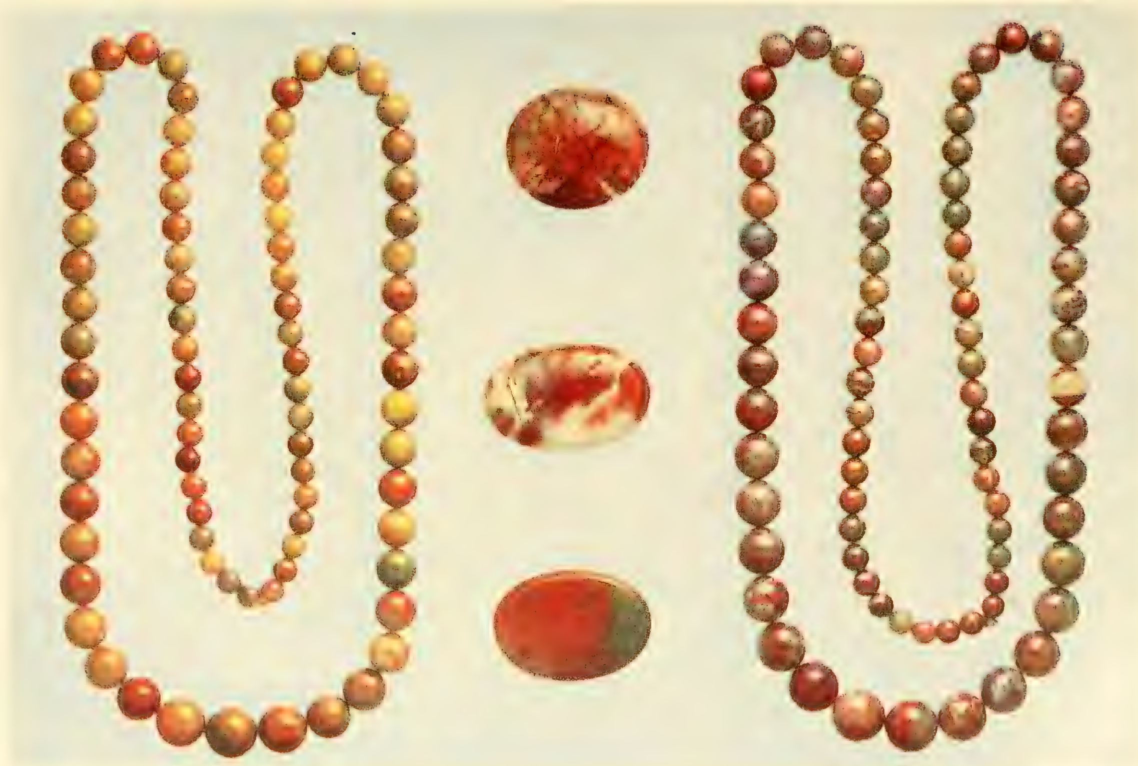
The opal, while classed as quartz, differs from it and the variety chalcedony in that it is never crystallized and carries a small amount of water in its constitution. It is perhaps difficult to imagine anything so insoluble as a silica existing in the form of a jelly; yet this is the early stage of the opal. Deposited thus in the cavities of volcanic rocks, in the interstices of silicifying wood, or in other favorable places, it undergoes a slight dehydration and shrinkage, whereby lines of strain or minute fractures develop that throw back the light rays and give the "fire" which constitutes the chief source of an opal's charm. One of the most beautiful of gems, it is yet one of the most treacherous, being endowed with what is truly the "fatal gift of beauty," for the lines of strain or fracture which throw back the light to give such radiant effects, may give way and the stone fall to pieces.

Opal as a mineral is widely distributed and abounds in regions of early volcanic activity. Much of this material is white or of various pale tints and termed *milk* or *common* opal. Another variety, found in the air holes of certain lavas, is as limpid and transparent as glass and hence called *hyalite*. Only rarely does hyalite show the fire that makes it desirable as a gem.

With a hardness of 6, opal belongs in the category of comparatively soft stones which discourages its use where it is likely to encounter much wear. While well suited for pendants, brooches, and similar forms, if mounted in rings it must be carefully protected by the setting. In spite of this handicap the opal ranks among the aristocrats of gem stones—the six so-called precious stones. One need look for no other explanation than the unique quality of its beauty. The opal has proved, so far at least, inimitable. In a superb stone the play of radiant colors has no equal, even surpassing a sunset, so that many consider it above all others the most beautiful of gem stones.

The oldest and most noted of all opal localities, from which possibly the Romans obtained their gems, lies in northern Hungary at Czerwenitza. The Hungarian stones are well known in the trade and quite characteristic

PLATE 55



Beads and cut stones of silicified wood, Fossil Forest, Arizona

in appearance. Upon a milk-white background small points of red, blue, and green form a mosaic of changing hues. The Hofmuseum at Vienna possesses the finest of the opals from this region including one single mass as big as one's fist, showing the most exquisite play of colors. This stone ranks among the finest and largest opals in the world. The Czerwenitza mines have been worked so long and so actively as to now yield few stones larger than a hazel nut. In early times farmers of the neighborhood exploitated the deposits, finding many of the finest stones while plowing or in rills left by the rains. Later the government took over the mines and introduced systematic underground-mining methods. The rock containing the gems is an old volcanic lava of the type known as trachyte, very much decomposed.

The inhospitable desert regions of Queensland, New South Wales, and South Australia produce many fine opals. Those from Lightning Ridge surpass anything produced elsewhere. Gems from this locality have a unique splendor, reflecting the fire of their sun-baked hills. Their colors are endless, the golden green and the reds being the most highly prized, the blue and the greens only slightly less so. The best gems occur in nodular form roughly resembling an olive in size and shape and bear no likeness to precious material until chipped or broken. Scattered in a sandstone, these nodules are often encountered unexpectedly, and many fine gems have been broken before their presence was suspected.

The mines situated in the Virgin Valley, Humboldt County, in northwestern Nevada near the Oregon state line, yield beautiful opals. They have a strong tendency to crack after extraction from their mother rock, and in this respect have proved a disappointment in the trade. Now, however, a system of "curing" has decreased this tendency to flaw. In variety the Nevada opals have no peers, ranging from clear, transparent forms with broad flashes of color to coal-black stones with vivid flashes of red, blue, and green.

Their occurrence here presents peculiarities unique among gem deposits. They are contained in a fine-grained volcanic ash which spread over the landscape during some early and violent volcanic eruption. (Plate 56.) The fall engulfed a forest of stately conifer trees and the animals that roamed it, much as the ashes of Vesuvius engulfed Pompeii. The trunks, limbs, bark, and even the cones of the trees have been converted to opal by waters carrying the soluble constituents of the ash. In many instances the wood has changed to common opal, but with streaks of the precious material; or an entire limb may be converted to the precious variety, often with the outer surface more brilliant than the center. The rich black masses with their fire of peacock colors occur about the outside of the large logs, and may, perhaps, represent the bark. The National Museum has a number of fine opals from this locality, chief of which is a deep black mass weighing over 16 ounces, rich in flashes of red, green, and blue, and said to be the largest mass of precious opal known.

Idaho, Nevada, and a few other localities produce fine opals in the steam cavities of old lavas. While of excellent grade the quantity and size do not permit of profitable mining.

A number of states of Mexico, notably Queretaro, Hidalgo, Guerrero, Michoacan, Jalisco, and San Luis Potosi, contain opal mines. The most important locality centers about La Esperanza near the city of Queretaro, where the stones are cut. The smaller and poorer Mexican stones sell by the handful, but the finer ones command high prices, and while usually considered inferior to opals from Australia and other localities, they have their own peculiar type of beauty. The Mexican opals are pellucid, with innumerable small but brilliant flashes of color. In many—the so-called *fire opals*—the base is honey

Opal diggings, Virgin Valley, Humboldt County, Nevada. (From photograph by D. B. Sterrett, U. S. Geological Survey)

yellow with yellow, green, and red flashes. Many are white with numerous small points of light.

The opals of Mexico occur in the cavities of old volcanic lavas rich in silica. This rock is usually red, light pink, or gray. At La Esperanza the character of the opal varies with the character of the rock. Where the rock is red, opals with a fiery red color abound; where the porphyry is lighter or mottled, lighter colored stones are the rule.

The cloud of superstition that condemned the stone as unlucky has long hampered the market for opals. Even in this enlightened age the superstition persists. How it arose is uncertain. The ancients thought opals bestowed nothing but good, and, judging from Pliny's account of the famous "Opal of Nonius," the Romans set great value upon it. Kunz, however, doubts whether the stone in question was really that to which we now give the name.

Sir Walter Scott is accused of being in a great measure responsible for the present-day superstition because of his use of the opal in *Anne of Geierstein*, although his readers have nothing to indicate that he intended to represent the stone as an unlucky emblem. It is said that the Empress Eugénie of France would not wear an opal because of this superstition, but the stone was a favorite with Queen Victoria, who presented each of her daughters on their marriage with jewlery set with opals.

The Topaz

Although various stories have arisen relative to the discovery of topaz, authorities seem to agree that the name came from *Topazos*, an island in the Red Sea. It is supposed also that the topaz of antiquity was the chrysolite, or peridot, of modern times, to which confusion may possibly be due the conflicting tales of its discovery.

Topaz, a fluosilicate of aluminum, belongs among the hardest of minerals, ranking next to the sapphire and ruby. It has a high index of refraction and good luster and is usually associated in the popular mind with a distinctive yellow color, often referred to as *topaz yellow.* Actually, however, colorless stones as well as those of a light blue occur quite as commonly, and other shades known include light green, usually with a tinge of blue, more rarely light rose, and very rarely deep red. (Plate 61, Figure 5.) Many large, clear, nearly colorless pieces, termed by the Brazilian miners "*pingos-da-agua*" (drops of water), are found in Brazil. The yellow stones come in many shades: golden, honey, wine, and brownish yellow, or deep reddish brown. The blue and green stones are always light in shade, often the color of light aquamarines, which they closely resemble. Natural rose-colored stones are rare. The yellow topaz is nearly matched in color by the golden variety of quartz called *citrine*, especially that from certain localities of Brazil. Fraudulent or ignorant substitution of this material has now reached such proportions that one must definitely specify *precious topaz* in order to ensure a genuine stone.

Topaz occurs as a product of secondary replacement in the pegmatite veins of granitic rocks, associated with cassiterite (tin ore), tourmaline, fluorite, and other minerals of like habit. Similarly it abounds in drusy cavities in granite with microline and albite and often with aquamarine, amethyst, and other semi-precious stones. In the *lithophysae* (rock-bubbles) of certain lavas, especially the kind called rhyolites, topaz often occurs, usually with tin ore or bright red manganese garnets. Much of the best material for gem purposes is recovered from the beds of streams.

Brazil, favored by nature with abundant beryl and amethyst, likewise leads the world in topaz deposits. The Rio Jequetinhonha near the village of Arrasuahy has yielded several very large crystals. The National Museum has two sections of different crystals; one in the Roebling collection weighs 45 pounds; another in the

Canfield collection, 95 pounds. Near the City of Ouro Preto, State of Minas Geraes, another locality produces the light golden-yellow stones. (Plate 61, Fig. 5.) These occur embedded in a stiff clay that has resulted from the weathering of the mother rock of clay slate. From these same mines come the very rare delicate rose-colored topaz. The yellow stones mined there will also assume a fine pink color when carefully heated, a peculiarity taken advantage of by the trade and accounting for most of the pink topaz sold in the shops.

Fine blue topaz is found at Alabaschka, near Mursinka in the Sverdlovsk region of the Ural Mountains, Siberia. It occurs in cavities in granite associated with smoky quartz and other minerals. Nearly all the larger mineral collections possess examples. The Urulga River, in the Transbaikalian region produces important quantities of dark honey-yellow, brown, or light-blue crystals, some exceeding thirty pounds in weight. Topaz found in Mino and Omi Provinces, Japan, includes colorless, wine-yellow to brownish-yellow, pale-blue, pale-green and brown varieties. The Japanese stones reveal an unusual property in that they gradually change color after lengthy exposure to light, the brown and yellowish-brown turning blue and the blue fading to colorless.

American sources of topaz, while widespread, have no commercial importance. The region about Pikes Peak, where the mineral occurs in cavities in granite associated with amazonstone, smoky quartz, and other minerals, leads in production. The color is very light blue, or green, and sufficiently clear and flawless to allow cutting into stones exceeding 100 carats in weight. Second to Colorado, comes Ramona, San Diego County, California, where fine blue crystals equal to those of Mursinka occur in pegmatite ledges, associated with beryl and fine hyacinth garnet. The red granite of the region near Streeter, Mason County, Texas, produces light-blue or green crystals of good size. This region has yielded the largest crystal yet found in North America, a light-blue stone measuring some 17 by 19 centimeters and weighing 1,295 grams, now in the collection of the National Museum.

Several places in the United States and Mexico produce yellow topaz in the lithophysae of rhyolitic rocks. The finest specimens come from the desert region of central Utah, especially Topaz Mountain in the Thomas Range, forty miles northwest of the town of Deseret. The crystals, either colorless or a fine wine-yellow, occur loose upon the surface of the ground, where they have weathered out of the mother rock, or in cavities in the rock itself. The latter make handsome mineral specimens but unfortunately the crystals come too small for cutting stones exceeding a carat in weight. Similar occurrences exist near Nathrop, Chaffe County, Colorado, associated with red manganese garnets. In Mexico topaz is abundant near San Luis Potosi, with cassiterite (oxide of tin); at La Paz in the State of Guanajuato; and in the State of Durango it is recovered from the placer operations for tin.

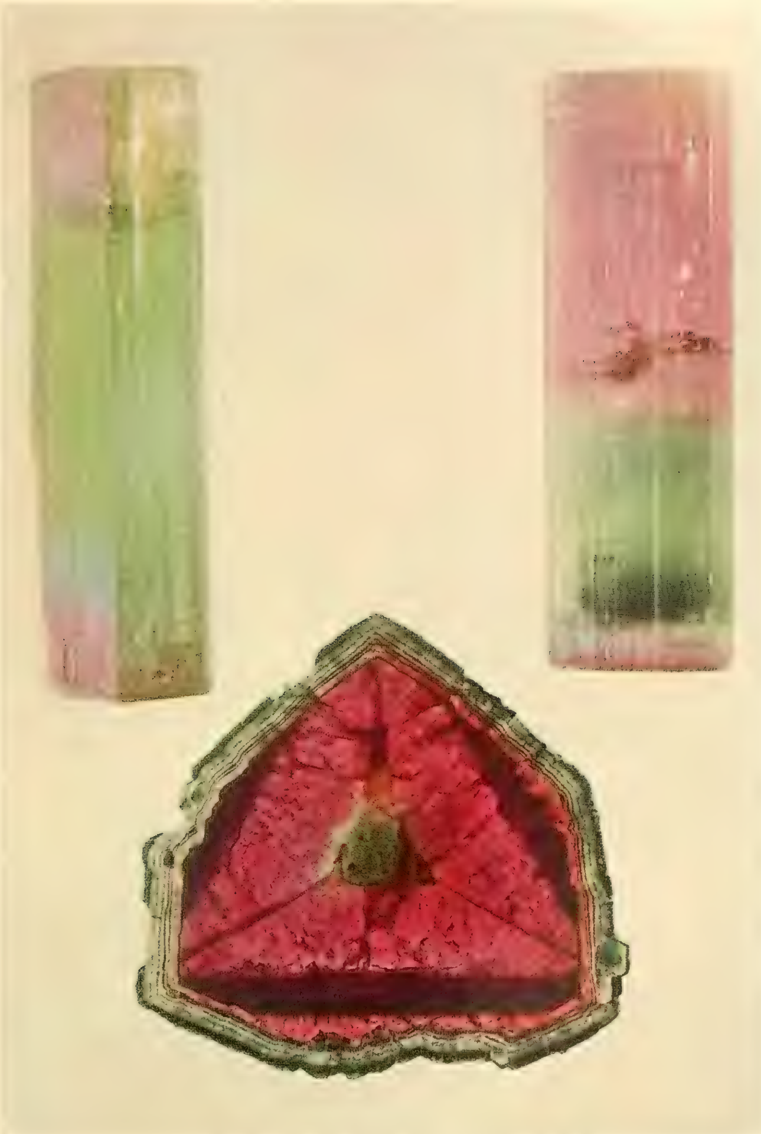
A few minor localities in the eastern United States, notably Stoneham, Maine, have supplied some fine colorless stones.

MYSTICAL PROPERTIES

Topaz symbolized friendship. Blessed with extraordinary power it might prove a friend indeed. It cooled boiling water; became opaque on contact with poisons; restrained anger and desire; cured insanity; checked the flow of blood; cleansed hemorrhoids; averted sudden death; and imparted strength and good digestion. Powdered and taken in wine it cured asthma and insomnia.

The Tourmaline

Although the tourmaline may have had a place among the gem minerals known to the ancients, history does not so record it. Not until the early eighteenth century was



Tourmaline. Crystals from Mesa Grande, California; Cross-section from Tsilaizina, Madagascar

its identity revealed. As the tale goes, some children of Holland, playing with stones given them by lapidaries, noted the strange attractive powers developed by their exposure to the heat of the sun. This incident, coming to the attention of the scientifically inclined, served to introduce to the world one of the most interesting of the many gems with which nature has supplied us.

Among the early names applied to it, "*aschentreckers*" or "ash-drawers," assigned by the parents of the Dutch children, came perhaps first. "Schorl," a subsequent title, afterwards gave way in favor of "tourmaline," from its Singhalese name, *turamali*.

North America, notwithstanding its poor repute as a producer of precious stones, stands first among the sources of this gem, the tourmaline. While fine examples come from Brazil, Madagascar, and Siberia, none has the wondrous colors of Maine's tourmalines nor the size and quality of those of California. In its chemical composition the tourmaline is a complex silicate containing boron and aluminum. Additional substances characterize the different varieties. Thus the pink, green, and blue tourmalines carry soda, potash, and lithia, the brown and opaque green varieties carry much magnesia, and the black, iron. Notwithstanding this wide variation in chemical make-up, very little difference appears in the crystal forms, which are usually prismatic with their long dimensions deeply striated. Whenever both ends terminate in crystal faces, one end will differ from the other.

No other mineral shows such variation in color in the same crystal or in crystals from the same locality as the tourmaline. They range from colorless to black, and through all shades of red, green, and blue. The colors may be distributed laterally as in those from California and Brazil, or concentrically as in some from Maine and Madagascar. The black varieties find no favor as gems, and rarely do the colorless and brown. The reds and greens, varying from light rose to dark red and light to dark green, prove most popular. A variety from Siberia so nearly approximates the color of the ruby as to make it almost indistinguishable when cut. As noted elsewhere, recent examination of the famous large ruby of Catherine the Great is reported to have identified it as one of these ruby-red tourmalines. The green stones range through yellow, blue, and rarely, emerald-green. Blue stones are usually too dark for use as gems, although small ones of a fine sapphire shade have come from Brazil and from Mt. Mica in Maine. The yellows are rather rare and usually not sufficiently striking to win popularity, although a golden-yellow variety from Madagascar ranks with our finest yellow gems.

Other striking color combinations particularly characteristic of the Maine tourmalines include the so-called "watermelons," which have a thick center of a deep-pink shade with a thin outer band of green. Still others have a light-blue center with a thin band of pink followed by an outer zone of green. The concentrically banded tourmalines of Madagascar reveal much more complicated color combinations, the zones frequently repeating many times, usually in shades of pink and green, often with fine line-like bands of blue. (Plate 57.)

The California tourmalines rarely show concentric bands, although a few are green in the center and pink outside. The more striking forms are longitudinally banded, as for instance the wonderfully beautiful crystals from Pala, one half deep pink and the remainder clear green (Plate 57). The larger ones from Mesa Grande usually show a uniform pink, capped with green, or with varying sections of green, pink, and salmon. Similar crystals but of different shades of green and pink are found in Brazil. From Elba come colorless crystals capped with dark brown to black, popularly dubbed "nigger heads."

The locality at Mt. Mica, near the town of Paris, in Oxford County, Maine, was discovered in 1820 by two

Tourmaline-Feldspar mine, Auburn, Maine. (From photograph by D. B. Sterrett, U. S. Geological Survey)

students and amateur mineralogists who spent much of of their leisure time searching for mineral specimens among the exposed ledges about the village. Returning one day from such an expedition, they found in the roots of an upturned tree a clear green crystal which Professor Silliman of Yale University later identified as a tourmaline. Further search of the region in the following spring resulted in a find of some thirty more crystals. Since that time the ledges have been worked from time to time and occasional pockets found yielding the wonderful stones which gave fame to the region. Harvard University possesses the finest collection of Maine tourmalines, containing the early collection of A. C. Hamlin, one of the first to systematically explore this locality for tourmaline. A number of the finer crystals were cut into gems for which their color rendered them eminently suitable. A fine green gem of 58½ carats, one of the largest cut stones, is now in the Isaac Lea collection, National Museum (Plate 61). Other localities in Maine, notably Mt. Apatite at Auburn (Plate 58), have also yielded tourmalines, but nothing has been found to equal the stones of Mt. Mica.

While the California tourmalines fall below Mt. Mica's stones in beauty and color, they surpass them in size and crystal perfection. In fact, no locality known produces the equal of the California specimens in this respect. Many of the larger crystals exceed 5½ inches in length and 3½ inches in thickness, and a large number with the crystal faces developed at both ends have been found. Tourmalines were known from California as early as 1872, and Indians and cowboys picked up crystals for a number of years before the locality began to attract notice. The first commercial exploitation took place in the region which has produced the red tourmaline crystals in lilac-colored lithia mica, seen in every collection. An attempt was first made to utilize this material as a marble, but without success. The mica is now actively mined for use in the manufacture of opalescent glass.

The tourmaline-bearing belt lies in San Diego and Riverside Counties and includes, as the principal localities, Mesa Grande, Pala, and Coahuila Mountain. Of these Mesa Grande is by far the most interesting locality, having yielded the large and magnificent crystals and groups seen in some of the museums. One of the finest of these belongs to the Roebling collection of the National Museum (Plate 59). The region abounds in veins of pegmatite rock but only a very few of them have yielded tourmalines suitable for gem stones. The minerals occur loose in cavities or in pockets associated with other minerals containing lithia, as lepidolite, the lithia mica, and spodumene, a silicate of alumina and lithia. Generally these "pockets" are too small and infrequent to justify mining operations, but the pegmatite at Mesa Grande constituted for a time a succession of large pockets, the like of which may perhaps never be seen again in this area. (Plate 60.)

A few other localities in the United States have produced some fine tourmalines, notably Haddam Neck, Connecticut. Here the occurrence resembles those of Maine and California, but the tourmaline, although of very fine quality, is never abundant. Bright-green stones are the rule. Many of the finest have gone to the collection of Yale University. Chesterfield and Goshen, Massachusetts, also have produced a few colored tourmalines.

For the commoner varieties, localities abound. Especially is this true of the black tourmaline, which exists wherever the colored stones occur. Unusually fine crystal groups come from Pierrepont in Saint Lawrence County, New York. Brown and green magnesian tourmalines, less abundant than the black, have been found at Gouverneur, DeKalb, and Macomb in New York and at Franklin, Newton, and Hamburg in New Jersey.

The best known of the foreign localities for tourmaline is the Ural Mountains in the region about Ekaterinburg, especially near the village of Mursinka. The mineral

Group of tourmaline crystals, Mesa Grande, California. Roebling Collection, National Museum

occurs here with amethyst, aquamarine, and topaz, in pockets in a granitic rock. From this locality come the fine ruby-red tourmalines noted above. The famous aquamarine and topaz locality of Nertschinsk in Transbaikalia reveals a strange poverty in good tourmalines, although a few are found.

The tourmaline ranks among the commonest of the gem minerals produced in Madagascar. Uniformly colored crystals are rare, by far the greater number showing either longitudinal or concentric bands with pink, green, and other colors. Brazil produces a large number of good green stones as well as some of salmon and other colors. A few colored tourmalines come from Ceylon and Burma. In the latter place they are dug by Chinese and sent to China, where the pink and rose-colored stones are highly prized.

Garnet

The name garnet, from *granatum*, a pomegranate, whose seed the crystals are thought to resemble, covers a group of minerals alike in form of crystallization, hardness, and insolubility, but widely variant in color and chemical composition. The prevailing colors include red, brown, yellow, black, and green. Colorless stones occur but rarely. Specific names depend on these chemical and color variations, resulting in a division into three prominent groups with several subdivisions under each, and grading into each other, as follows:

1. Aluminum garnet:
   - Grossularite—Lime-aluminum garnet (essonite, hyacinth).
   - Pyrope—Magnesium-aluminum garnet.
   - Almandite—Iron-aluminum garnet.
   - Spessartite—Manganese-aluminum garnet.
2. Iron garnet: Andradite—Calcium-iron garnet.
3. Chromium garnet: Ouvarovite—Calcium-chromium garnet.

The lime-aluminum garnet has a hardness of 7, a specific gravity of 3.55 to 3.66, and a considerable color range. The several varieties include essonite (cinnamon stone or hyacinth) of which the specimens of a clear yellow-brown to deep gold tinged with brown are more commonly used as gems; grossularite, which comprises the pale-green, yellow to nearly white, pale-pink, red-orange, and brown kinds; romanzovite, a brown variety; wiluite, yellow-green to greenish white; topazolite, deep to pale yellow; and succinite, amber-colored.

The principal magnesian garnet is the pyrope, a term meaning "fire-like," a deep-red to nearly black stone, prized as a gem.

The almandite, or carbuncle, and rhodolite are iron-aluminum garnets. Almandite varies in color from bright red to deep red of several tints, occasionally assuming an orange hue by artificial light. The color of the rhodolite lies between a violet-purple and a brown-red. Both find high favor as gems.

Spessartite is a manganese-aluminum garnet. The color varies from a red-brown, sometimes with a tinge of violet, to orange-red. It often affords fine gems.

The calcium-iron garnet varies in specific gravity bebetween 3.6 and 4, and in hardness from 5 to 7. The group includes a diversity of forms, varying widely in color and other respects, the more important of which are: andradite, a yellow or orange-brown variety; demantoid, or Uralian emerald, a grass-green, emerald-green, or brown-green stone having a brilliant luster, and when cut exhibiting considerable fire, especially by artificial light; colophonite, a brown-black garnet, characterized by a resinous luster; and melanite, a black to yellow-brown kind.

The calcium-chromium garnet, ouvarovite, is almost invariably a fine emerald-green color, and is harder than any of the other varieties, ranking nearly 8 in the scale.

Garnet occurs commonly in mica, hornblende, and

Tourmaline mine, Mesa Grande, San Diego County, California.
(Photograph by W. T. Schaller, U. S. Geological Survey)

chlorite schist, gneiss and granite, and also in limestone, serpentine, and volcanic rocks. Iron garnets appear frequently in eruptive rocks, occurring also as a product of contact metamorphism. Demantoid occurs in serpentine, while the chrome garnets belong particularly to serpentine.

The mineral finds wide use as a semiprecious stone, although the color in some cases attains so deep a shade as to deprive it of popularity. The most noted garnet region in the world is that some sixty kilometers north of Prague in Bohemia. For many years this has been almost the only commercial source of the common ruby garnet found mounted in various and multiple forms in the jewelers' shops.

Of late years a great many very beautiful garnets have come in from the Indian reservations in Arizona and New Mexico, picked up from the loose sands and gravels which result from a decomposition of bowlders of garnetiferous gneiss. According to Gregory, igneous injections have brought these to the surface from an unknown depth. They are often of no mean quality and are popularly spoken of as Arizona rubies. The principal localities are the Mule Ear and Moses Rock fields in southern Utah and the Garnet Ridge field in the adjoining portion of Arizona. The garnets of this region range in size up to three centimeters in diameter, but the large forms rarely come perfect. The better grades do not attain over ten to twelve millimeters in diameter, and the majority of stones not over eight millimeters. In color they vary from a rich wine red to lighter shades.

Garnets are hard and difficultly soluble under natural conditions. Hence they accumulate with other less destructible constituents of rocks in the sands resulting from rock disintegration and may be found as small red granules in the sand of almost any sea beach along gneissic or granitic coasts, or distributed throughout the loose material overlying a decomposed rock.

A white massive form occurs associated with the variety of vesuvianite called *californite* found in northern California. Usually this stone goes abroad for cutting; in American shops it is often sold as white jade.

San Diego County, California, has produced excellent gem garnet. Fine examples of the essonite variety have been found in the foothills of the desert near Dos Cabezas Springs, but the finest come from mines in the vicinity of Ramona, where they occur in pockets in pegmatite veins, implanted on feldspar and associated with green tourmaline, white and blue topaz, and beryl. These stones run from a rich honey-yellow to orange-red in color, and when without flaws make handsome and brilliant gems. A similar garnet, light orange-brown in color and quite brilliant, though rarely free from flaws, has been found in the pegmatites of Amelia, Virginia, where it occurs in albite.

A very beautiful stone, called rhodolite from its deep rose color, occurs in the Cowee Creek region of North Carolina—the same district which has yielded some rubies. Their fine red color and remarkable brilliancy make them highly desirable as gem stones. A few have been cut into gems of over ten carats, but large stones are rare. Although considered the chief gem mineral of North Carolina, little is now being done toward its production.

Gravel washing for gold in streams near Custer, South Dakota, has brought to light incidentally some beautiful red garnets. Small stones appear frequently, but no large, flawless gems suitable for cutting.

The common almandite variety sometimes occurs in such quantity that it is recovered by crushing the mother rock, ground, bolted, and utilized as an abrasive.

Rich in color and durable, garnet possesses many of the qualities desirable in a gem stone. The Romans made frequent use of it for engraving and some notable examples of their art exist. The celebrated Marlborough

1. Zircon. 2. Tourmaline. 3. Tourmaline. 4. Chrysolite (Peridot).
5. Topaz. Roebling and Isaac Lea Collections, National Museum

garnet, engraved with *Sirius*, ranks as a masterpiece, while the magnificent *Atalanta* in the Berlin collections is said to be the finest of the Greek school. In modern times the garnet seems to have lost its popularity. When now seen at all, the stone is apt to form part of old fashioned pieces of jewelry handed down as heirlooms. This loss of favor seems strange, since the reds approached the ruby in color, and the other fine shades, especially the green (demantoid), do not lack beauty. Perhaps the garnet's present eclipse illustrates the claim that, in this day, a thing must be rare to be appreciated.

MYSTICAL PROPERTIES

According to the *Puranas* of the ancient Hindu poets, garnets when colored like the conch, the lotus, the black bee, or the sun, strung on a thread, herald good fortune. A garnet colored like the crow, the horse, the ass, the jackal, the bull, or the bloodstained beak of a vulture holding a piece of flesh, is a harbinger of death.

CHRYSOBERYL

The mineral *chrysoberyl*, a compound of the elements beryllium and aluminum, possesses the desirable characteristic of hardness, being 8.5 in the scale and approaching corundum. This property renders it eminently suitable for gems. The yellow-green to grass-green material suitable for cutting resembles very much the gem peridot, so much so in fact as frequently to cause confusion. The translucent stones often have a chatoyant sheen, so that gems cut in the proper manner give the effect of the cat's-eye so pronouncedly as to be marketed under the name of chrysoberyl or Ceylon cat's-eye. Those gems are most highly prized which show the line of light like a thin silver thread which moves from side to side with the turn of the stone.

Chrysoberyl occurs abundantly in the district of Minas

Geraes, Brazil, associated with topaz and other stones already described. The streams yield it in pebbles seldom larger than a bean, although the finding of a mass weighing sixteen pounds has been reported. Fine sulphur-yellow stones come from the gold-bearing gravels of the Sanarka River in the southern Urals in association with pink topaz and other minerals. Ceylon produces many chrysoberyls, mainly the cat's-eye variety.

The mineral exists in association with tourmaline, garnet, and beryl in the granitic pegmatites of New England, but never in gem quality. A twin-crystal form, highly prized by mineralogists, is sometimes found; two very remarkable specimens from Minas Geraes, Brazil, form part of the Roebling collection.

The gem alexandrite constitutes a unique variety of chrysoberyl first found in the emerald mine of Takowaja in the Urals of Russia in 1830, on the day that Czar Alexander II attained his majority, a circumstance which caused it to be named in his honor. For this reason, and because it shows the military colors of Imperial Russia, green and red, it became a great favorite there. Some of the crystals reach a size of nine centimeters and those of four centimeters are not unusual. Only small portions of these qualify for gems, so that one rarely sees stones of any size. Alexandrite ranges from dark grass- to emerald-green, and betrays the peculiar property of changing color to a raspberry red in artificial light. This remarkable change results from the absorption of much yellow light. Exposing the stone to combined rays of natural and artificial light will cause the individual facets to reflect various colors—light green, golden, salmon, or red, depending upon the position in which the gem is held. In subsequent years much larger and finer stones appeared in Ceylon. Bauer mentions a gem of 63⅜ carats from this locality as being the largest known when he wrote in 1896. The Isaac Lea collection in the National Museum now contains one of over 65 carats.

MYSTICAL PROPERTIES

As an amulet the chrysoberyl dispelled evil dreams, fear, and melancholy. The cat's-eye has long been highly esteemed as a preserver of good fortune and is used by the natives of Ceylon as a charm against evil spirits.

Chrysolite

Mineralogists suppose chrysolite to have been the "topaz" of the ancients. It has at times been very popular as a gem stone under the poetical name of "evening emerald," though the term peridot serves generally to identify it in the market.

Chrysolite is a ferruginous silicate of magnesium and occurs most commonly as a constituent in scattered granules of the volcanic rock, basalt; it sometimes forms the prevailing constituent in a group of igneous rocks known as peridotites; and it is also found in many meteorites. In color the mineral ranges from yellow-green to deep bottle-green, sometimes transparent but more commonly only translucent. (Plate 61, Fig. 4.) It rates as 6.5 in the scale of hardness, has a high refractive index, and hence in its better grades serves well for gem purposes.

The ancient sources for chrysolite have for the most part dropped out of the record. Recently old mines on the Island of St. John in the Red Sea came to light again to be worked for a while by the ex-Khedive of Egypt. The mineral occurs here in beautiful flawless crystals of a deep yellow-green color. Chrysolite forms the chief constituent in the rock composing the small island. The fine crystals appear in veinlets on the eastern side but the supply of material suitable for gems of the first grade is said to be limited.

Peridot has often passed for emerald and many of the large "emeralds" in the ecclesiastical and royal treasures of Europe are, it is reported, in reality chrysolite. A very fine stone weighing 310 carats, now in the Roebling collection of the National Museum, is said to have once adorned the figure of a saint. This stone probably came from the Red Sea locality.

In the United States the gem variety apparently occurs only in areas of disintegrated igneous rocks within the Navaho Indian Reservation of Arizona and New Mexico, scattered in the form of small, dull-green pebbles in the superficial sand and gravel. The mineral forms an abundant constituent of a basic igneous rock composed largely of chrysolite and enstatite, the first-mentioned often much altered to serpentine. The rock weathers rapidly, breaking down to a loose sand and gravel from which Indians gather the gem stones. The grains occur in varying sizes up to four millimeters in diameter. The area is infested with ant hills a foot or more in height, some of which contain up to seventy-five per cent of olivine grains. They are not, however, brought to the surface by the ants as some have imagined, but form the basic constituent of the soil of the surrounding region.

Spodumene

The particular interest in spodumene, a silicate of lithium and aluminum, arises from its remarkable color range and from the pleochroism of the more highly colored varieties, hiddenite and kunzite. The mineral occurs in granitic pegmatites of the same general type as those furnishing the commercial feldspar and mica, but while quite common it is usually white and opaque or so considerably altered as to be of little value for gem purposes. In the early days of exploitation of the deposits of Stony Point, North Carolina, for emeralds, there came to light pockets in the gneissoid rock containing a large number of small emerald-green crystals of strange aspect. Detailed examination proved them to be the mineral spodumene, but so clear and brilliant as to appear totally unlike the mineral commonly known under this name. The beautiful color and fine luster of the stone eminently

Spodumene, variety Kunzite. Pala, San Diego County, California.
Roebling Collection, National Museum

fitted it for gem purposes. To distinguish it from the commoner opaque form, it received the name *hiddenite.*

The first crystals found lay loose in the soil but later prospecting revealed their original home to be in clefts and cavities in the underlying gneiss in association with crystals of quartz, feldspar, rutile, emerald, and other minerals. The crystals never reach great size. The largest cut stones obtainable do not exceed five carats, and the majority do not weigh more than one or two carats. No other locality in the world has produced spodumenes of this color. Since the number of good gem stones found did not suffice to pay the cost of mining, operations at the deposit have ceased and one seldom sees the gem outside of collections. Perhaps the finest rough crystal forms part of the Bement collection now in the American Museum of Natural History in New York.

In the famous tourmaline mines at Pala, San Diego County, California, there came to light in 1902 a mineral of a pink color, fine luster, and strong pleochroism which defied determination by local prospectors and jewelers. A mineralogist later identified it also as spodumene, but of a color and transparency never before encountered (Plate 62). It immediately became a favorite as a gem stone, selling in this country under the name *kunzite,* after George F. Kunz, the gem expert. Abroad it is often called iris. Crystals from the Pala Chief mine present an especially fine and handsome appearance; some of the largest measure over a foot in length, and possess a delicate pink color. These large crystals usually are flat, and since, to obtain the best color, the gems should be cut with the table across the crystal, one rarely sees large cut stones. Perfect gems of 75 or even 100 carats have been obtained, however, the largest in the National Museum collection weighing 75.9 carats.

Similar pink spodumenes have since appeared in Madagascar and while the crystals are not as large as those from California, the color is a deeper shade of pink. Spruce Pine, North Carolina, has yielded a single pocket of kunzite in a pegmatite mass. The largest crystal, weighing about 2½ ounces, is a deep lavender color, quite different from the California and Madagascar crystals. It now rests in the collections of the National Museum. Light greenish-yellow spodumenes, utilized to some extent as gems, abound in parts of Brazil. The enormous size of spodumene crystals surpasses any other crystal known. Examples from the Black Hills region of South Dakota, where it is mined as a source of lithium, sometimes attain a length of forty feet and a weight of several tons.

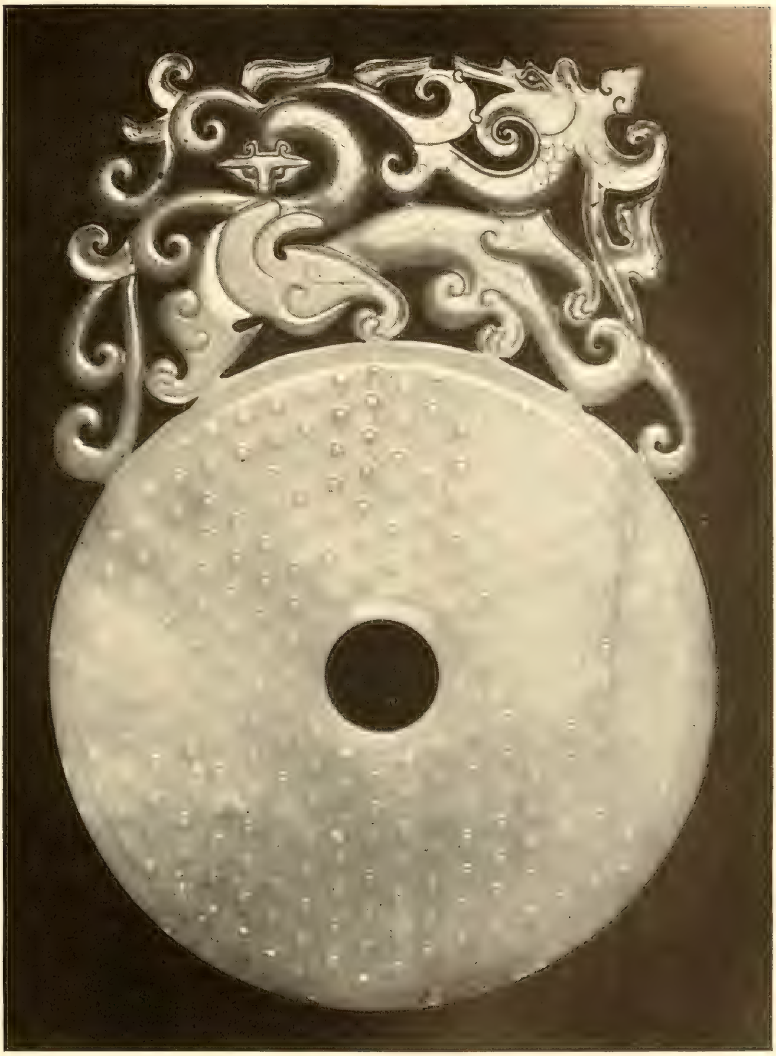
Benitoite

The ancients knew most gem stones used in modern times, and types discovered even comparatively recently have proved but variants of well known mineral species. In 1907, however, the mountainous region of San Benito County, California, yielded a new mineral eminently suitable for gems. This mineral, a silicate of titanium and barium, received the name *benitoite.* It was at first mistaken for sapphire because its color approximates the blue of that stone, but careful examination revealed a much greater pleochroism, or change in color when viewed in different directions.

Brilliancy, attractive color, and strong pleochroism distinguish benitoite as a gem. The depth of color varies in different portions of the crystals. Light transmitted perpendicular to the base is practically colorless, while parallel to the base it is blue. To secure the best effect the gem should be cut with the table parallel to the principal axis and not to the base, as is the rule for sapphire. The flawless gems seldom exceed a carat in weight; the largest cut gem known weighs about seven carats.

Benitoite occurs in veins of natrolite which traverse a glaucophane rock, and is associated with the rare mineral

PLATE 63



Chinese Han disk of jade. Freer Gallery

neptunite in very fine crystals. The association of the bright-blue benitoite with the brilliant reddish black of the neptunite and the pure white of the matrix of natrolite results in some of the handsomest specimens in mineral collections. The National Museum has a very fine slab, a gift of the mining company which has now ceased operations. One must regret that the production of this attractive stone should have been so limited.

Zircon

This mineral, in its finer grades, deservedly ranks as a precious stone. Only the diamond among gem stones possesses a higher index of refraction. Rarely colorless, the usual tint is some shade of red or brown, but green, blue, and violet stones are not unknown. The red (hyacinth) and the yellow (jacinth) furnish the most highly prized stones. A beautiful blue variety owing its color, some claim, to artificial means, has lately attained popularity.

Zircon occurs always in crystals, square prisms terminated by a four-sided pyramid, although when found in the beds of streams attrition may have worn the faces indistinct. The crystals frequently appear in granites, gneisses, and similar rocks, but all the precious material comes from the gravels of streams, where they have accumulated because of their resistance to decay. Many of the colored stones possess the peculiar property of losing color by heating, the result being either colorless or lightly tinted with yellow or gray. The colorless stones resemble the diamond to such an extent that the natural ones from Madura, Ceylon, were considered for many years an inferior form of that stone and called "Madura diamonds."

The stream gravels of Ceylon furnish the chief and only important source of gem zircon. The minerals form originally in the gneissic rocks of the island and win their freedom by the action of rains. India and Upper Burma have yielded some stones. In the United States zircon as a mineral is not uncommon. Many tons of it have been mined for refractory and other purposes in Henderson County, North Carolina. Very large and well formed crystals occur in calcite at Renfrew, Ontario, Canada, and in St. Lawrence County, New York. The gold bearing sands of North Carolina have produced a few richly colored stones of gem quality.

From the vicinity of the old sapphire workings north of Bangkok, Siam, have come the fine blue stones called *starlite* by Kunz, in allusion to a scintillating blue color. Some very large gems of this type have been found, weighing as much as forty to fifty carats. The Roebling collection in the National Museum possesses a cut stone of twenty-nine carats. (Plate 61, figure 1.)

Jade

The general term *jade* comprises two quite distinct minerals possessing in common a great toughness and a prevailing green color. The first, jadeite, forms a variety of pyroxene, a silicate of sodium and aluminum; and the second, nephrite, or amphibole, a silicate of calcium and magnesium. Casual inspection can not always easily distinguish one from another, though the jadeite shows, as a rule, a granular structure quite unlike the dense, fibrous structure of nephrite. While both show a prevailing green, the jadeite is often speckled or mottled green and white, while the nephrite is clouded in the same colors. Some of the nephrites, however, possess a beautiful milk-white color. The higher grades of both minerals find similar uses as carvings, beads, pendants, and brooches, for which purposes they are highly popular and exact corresponding prices.

Primitive man, where he could find jade, made eager use of it in shaping his ornaments and implements. The working of the material reached its height among the Chinese, and many of the objects made from it offer an illustration, excelled in no other line, of the slight value of time to the early artisans, years and even lifetimes being devoted to the completion of a single object of the larger and more complicated designs. (Plate 63.) In the beginning, no doubt, the Chinese obtained jade locally, but for centuries caravans brought material from the high Kuen Lun Mountains in eastern Turkestan, especially from Khotan and Yarkand, where the best grade of material occurs in the beds of streams. Marco Polo visited the region and described the method of recovery used, the searchers wading about in the stream while a supervisor watched from the bank. The workman could locate the precious bowlders by feeling with his feet. The nephrite variety also occurs in eastern Siberia along the Onot River, and in New Zealand.

Jade constituted the most highly valued of the gem stones of the Aztecs and other early inhabitants of southern Mexico. Two pieces given to Cortez by Montezuma were valued by the Aztecs at two cart-loads of gold. Great efficacy in the treatment of diseases of the kidneys was ascribed to it, and hence the Spaniards called it "*piedras de yjada*" (stones of the side). From this term, it is believed, came our modern name *jade*.

Where the ancient Mexicans obtained their jade remains unknown. The shape of many of the worked objects suggests that they found the mineral as rolled pebbles in the beds of streams, presumably somewhere in southern Mexico. Some believe that the mineral found its way from China, thus serving as further evidence of a close relationship between the ancient Mexicans and the Orientals. Recent investigations, however, have shown that the Mexican material differs in its chemical composition from any of the jades known to the Chinese. The Mexican jade has been called *tuxtlite* from a small statuette or idol in the National Museum, known as the "Tuxtla statuette."

No jade of the first quality has as yet been found in place on American territory. A dull, rather coarse variety came to light in what is now known as Jade Mountain, north of the Kowak River, and about 150 miles from its mouth, in Alaska. The natives used this material, a true nephrite, for knife blades and the like, and for ornaments.

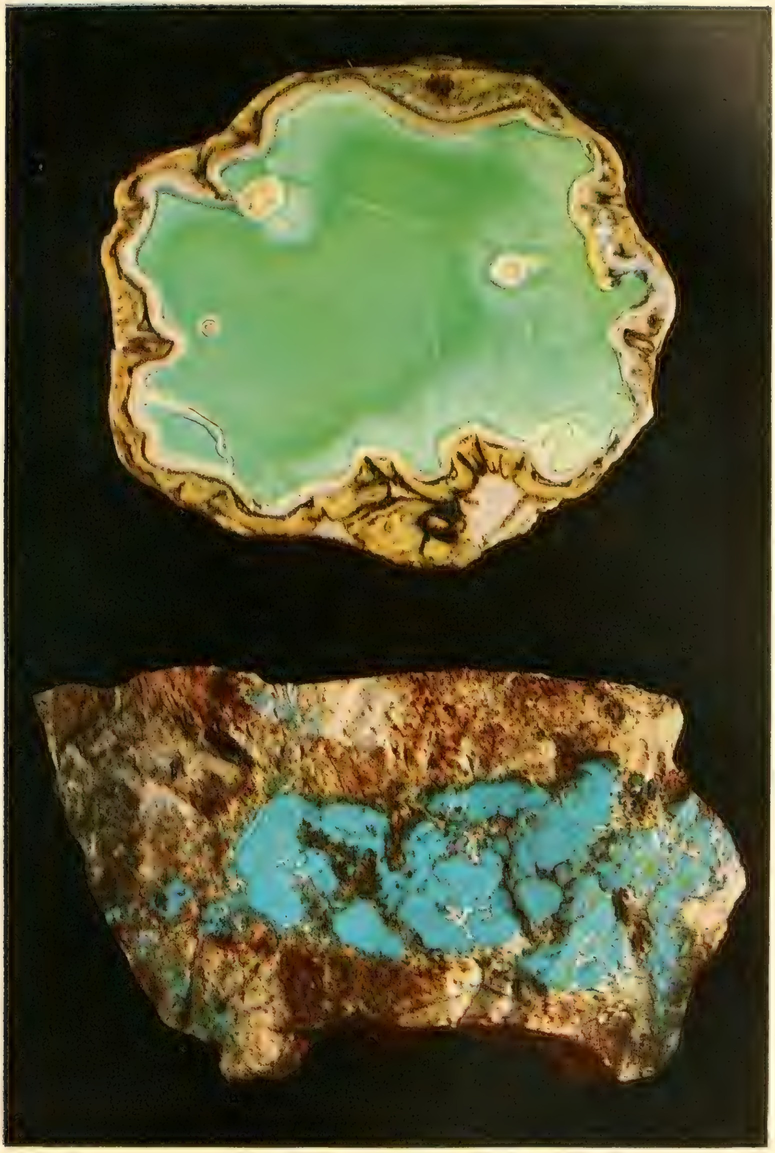
The district of Mogoung, Upper Burma, contains the most important deposits of precious jade, the source of the apple-green material seen so frequently in the markets today. Much of it is recovered as pebbles and bowlders from the river Uru about Sanka, but quarrying operations in the mother ledge also produce considerable quantities. The Uru mineral is jadeite and ranges in color from white to deep apple-green, usually mottled. A fine lavender tint distinguishes much of it, but this has been found of little use and is largely rejected. In many places the jade lies embedded in an iron-rich clay, the iron of which has penetrated the stone so as to give it a beautiful red tint. This is called red jade and is said to be highly esteemed by the Chinese. The material goes to Canton and Peking for carving into appropriate ornaments.

The popularity of jade leads to shameful counterfeiting with other green minerals. Massive varieties of green vesuvianite and white garnet from California serve as substitutes, as does also dense green serpentine, especially that from Manchuria known as "Yu Yen stone." Its inferior hardness renders this substitute liable to easy detection.

Turquoise and Variscite

In only two instances does phosphoric acid combine with bases to give rise to minerals of gem value, and in both of these instances the second base is aluminum, forming the minerals *turquoise* and *variscite.* (Plate 64.) Among all gem minerals, possibly no other has been so widely used, geographically or socially, as the turquoise. This seems the more strange when we consider that it is an opaque stone owing its popularity wholly to color.

PLATE 64



Variscite, Lewiston, Utah; and Turquoise in matrix, Los Cerrillos, New Mexico

In chemical composition the stone is a hydrous phosphate of aluminum and copper with minor amounts of iron. Almost universally it occurs massive and amorphous, and has a smooth fracture and porcelain-like luster. The color varies from some shade of blue to green. "Robin's-egg blue" meets with the most universal favor. The color does not always remain stable unfortunately, the fine blue sometimes passing into a less desirable green or even fading entirely to white. Either color may undergo further change if worn for long periods directly against the bare skin, where it absorbs the perspiration. The mineral often occurs in association with iron oxide of a chestnut-brown color, which forms small patches and reticulating veinlets through the green or blue material. Where the turquoise has filtered into fractures in the country rock, such material is called "turquoise matrix," and, when properly cut, may result in very beautiful stones. Europeans and Orientals prefer the uniformly colored stones but Americans hold the "matrix" in high esteem. (Plate 68, Figs. 6 and 8.)

Turquoise occurs throughout the world, though productive deposits are found only in Persia, Thibet, China, and the southwestern United States. In quantity and quality of little economic importance, Abyssinia, Nubia, Sinai, Turkestan, Bokhara, Afghanistan, Arabia, Australia, France, Germany, Siberia, Peru, Mexico, as well as other countries, have yielded the mineral. The finest turquoise comes from Persia, especially from the region about Nishapur, the most productive mines lying on the south flank of the mountain known as Ali Mirsai. The village of Maaden at its foot gains its livelihood wholly from working the mines and cutting the stones. The mineral occurs in a volcanic rock called *trachyte* which has been locally crushed into fragments and the interspaces filled with turquoise and oxide of iron. The history of these mines goes back beyond the records.

Beads found in prehistoric graves demonstrate the early use of turquoise in Egypt, and evidences of mining on the Sinai peninsula date as far back as 5000 B.C. No date can be given for its early use in Persia, where the ruling classes regarded it as scarcely suitable for their use. India, Thibet, and China apparently began the use of turquoise no farther back than the Middle Ages, when, as in Europe, it came into favor in the belief that it possessed medicinal qualities.

The southwestern part of the United States contains many known turquoise localities. Nearly all of the deposits show evidence of work by aboriginal man. The Spanish conquerors found the stone in very general use throughout the Southwest, particularly among the Indian tribes of the plateau regions of Arizona and New Mexico. Turquoise beads are also found in graves of undetermined antiquity. The mineral was used not merely for personal adornment, but for small carved objects and inlay work, marked by great skill and artistic ability of a high order.

To judge from the size of the prehistoric excavations, the region about Los Cerrillos, twenty-three miles south of Santa Fé, New Mexico, furnished one of the chief sources of aboriginal supply (Plate 65). A pit 200 feet deep and 300 feet in diameter gives mute evidence of a yield of many pounds of turquoise. There are two other deposits of quite similar character in this region, one about Mt. Chalchihuitl, two miles northeast of Cerrillos, and the other, Turquoise Hill, six miles northeast. The country rock is a severely fractured monzonite. Into the abundant fissures and joints thus formed, percolating waters have deposited the turquoise, and incidently produced much local decomposition of the rock. The mineral occurs in thin seams and veinlets, rarely over an inch across, and in the form of nuggets imbedded in the clay. The best material has a fine sky-blue color, even texture, and a hardness somewhat greater than that from other localities. Small ramifying seams, of a chestnut-brown color, cut much of it, forming very attractive material for cutting into matrix stones. The workings include pits, open cuts, shafts, and tunnels, in some of which ancient tunnels and stopes have been encountered.

Somewhat similar deposits have been worked in the Burro Mountains, Grant County, New Mexico, and although they have yielded a great amount of good turquoise, they seem to have been largely worked out. Granite forms the mother rock. The gem material occurs in small veins in the joints of a zone of broken rock, or in nodules in the claylike alteration of the mother rock. These nodules or "nuggets" proved to be of the finest quality, harder than much turquoise of other localities, and often of a very fine translucent blue color. This district produced much of the finest gem material found in the United States. Similarly fine material is mined in Mohave County, Arizona, and in the vicinity of Millers, Nevada.[10]

The occurrence of the mineral variscite in the United States, in form and quantity suitable for commercial purposes, was first made known through the publication of analyses made in the laboratory of the National Museum in 1894.[11] The first material came from near Lewiston, Utah; since then other discoveries have been made in Utah and in Nevada, and special trade names have been given to varietal forms, as *amatrice*, *utahite*, *wardite*, etc. The material varies in color from deep emerald or grass-green to pale shades or white, and in its higher grades bears a strong resemblance to the green varieties of turquoise, which it closely resembles in composition. Like the turquoise it occurs as a secondary mineral along zones of shearing and crushing in the country rock, which in this case is limestone rather than granite. The zone of crushing, or brecciation, is strongly mineralized by deposits

[10] Those interested may find a comprehensive history of the stone in The Turquoise, a Study of its History, Mineralogy, Geology, Ethnology, Archaeology, Mythology, Folklore, and Technology, by Joseph E. Pogue, *Mem. Nat. Acad. Sci.*, Vol. 12, Pt. 1, 3d Mem., 1915.

[11] R. L. Packard, *Amer. Jour. Sci.*, Vol. 47, p. 297.

of chalecedony, chert, variscite and allied phosphatic minerals, and small amounts of pyrite. The variscite generally occurs in nodular form in the chalcedony, sometimes with a distinct banding and gradation from the deep green to pale green and white. As with turquoise the material can be used effectively by cutting in connection with veinlets and particles of matrix, or associated minerals. Because of its opacity, it is generally cut *en cabochon*. Although closely resembling the greener shades of turquoise, it is readily distinguished by its inferior hardness which comes at 4 in the scale as against 6 for the turquoise. (Plate 71, Figs. 4 and 8.)

MYSTICAL PROPERTIES

The turquoise is emblematic of success. All Orientals value it highly and wear it to insure health and success. They suppose it to preserve the wearer from injury through accidents. In the presence of poisons the stone sweated profusely, a property thought to be characteristic of many of the noble gems. Its color paled as its owner sickened and disappeared entirely on his death, to be recovered only when it became the property of a healthy person.

Lapis Lazuli and Sodalite

The material known under the name *lapis lazuli* consists of a fine-grained limestone impregnated with the minerals lazurite, pyrite, and miscellaneous minor substances. This heterogeneous character reveals itself readily, especially upon examination with a lens. Lapis lazuli owes its value as an ornamental stone to the rich, deep-blue color of the lazurite, a sulphosilicate of sodium and aluminum. A deep azure blue is much preferred to the other shades of greenish blue, violet, and red-violet. Heating often intensifies the color and some material will darken upon long exposure to sunlight. Small golden points of pyrite frequently speckle the azure surface, likening the cut gem to a starry heaven. The mineral

Turquoise mine, near Cerrillos, New Mexico. (From photograph by D. B. Sterrett, U. S. Geological Survey)

adapts itself well to use as beads and pendants, and is extensively employed for making small trays, vases, and other works of art.

Various points in Siberia furnish the best gem material. Badakshan, on the northeastern border of Afghanistan near the headwaters of the Oxus River, a locality visited and described by Marco Polo, leads all others, though important deposits exist along the west shore of Lake Baikal in the vicinity of the town of Kultuck.

North America produces no material of a high grade, though stones unsuited for gem purposes have been found in the San Gabriel Range, near Upland, California, occurring as blue or greenish-blue streaks in a gray limestone. A better class of material abounds in the Chilean Andes, on the banks of the Rio Grande in the Cordillera of Ovalle, near the Argentine border. Here, as everywhere, the lapis occurs in limestone with granite nearby, to the intrusion of which the lapis lazuli probably owes its origin. Not only is it found abundantly in place, but numerous blocks and bowlders from the mother ledge are strewn about the vicinity. Much of the Chilean stone occurs in a greenish-blue color which renders it inferior to the Siberian material. It is veined and mottled with white calcite and often carries abundant pyrite. (Plate 71, Fig. 10.)

The mineral lazulite, a hydrous phosphate of aluminum, often confused with lapis lazuli (lazurite) owing to the similarity in color and name, has no use as a gem material. This mineral occurs in good crystals at Graves Mountain, Georgia, and at Breyfogle Canyon, near Death Valley, California. Another mineral, dumortierite, found in a number of places in the western United States, also readily lends itself to confusion with lapis lazuli but lacks the fine color of the real material. An imitation called "Swiss lapis" has a ready sale in the form of beads and other objects. This is not lapis lazuli at all, but a dyed chalcedony whose misleading name and low price make it a popular article on the market.

Sodalite is a silicate and chloride of sodium and aluminum, quite similar in appearance to lapis lazuli. It varies from colorless to deep blue and has been used to some extent both in decorative architectural work and in jewelry. Unfortunately, while of a beautiful sky-blue by daylight, it appears almost black by artificial light. The mineral has been found in coarse granular form in the nephelite syenites of Litchfield, Maine, and Bancroft, Ontario, and in the Ice River region of British Columbia.

The Feldspars

The feldspar group includes a family of closely related minerals which have a very wide distribution in the rocks of the earth's crust. Most of the occurrences, however, are of quite ordinary varieties, without striking color or optical effects; and hence, while of mineralogical interest and often of economic importance, are not suitable for use as gem stones. When they show colors of unusual brilliance or chatoyancy they are often cut into various shapes for personal adornment or for architectural decoration.

All feldspars constitute compounds of silica and alumina with soda, potash, or lime. They occur often in well-developed crystals, either monoclinic or triclinic in form. The more important members of the group include:

Orthoclase: A silicate of aluminum and potassium (moonstone in part).

Microline: A silicate of aluminum and potassium (amazonstone in part).

Albite: A silicate of aluminum and sodium (moonstone in part).

Oligoclase: A silicate of aluminum, calcium, and sodium (moonstone in part).

Labradorite: A silicate of aluminum, calcium, and sodium.

Anorthite: A silicate of aluminum and calcium.

All members show good cleavage and break easily with smooth planes. Indifferent hardness does not permit the mineral to stand rough usage. Commonly opaque, the feldspar colors usually include not particularly pleasing whites, yellows, browns, and reds. Among the colored feldspars only one, the green variety of microcline, usually called *amazonstone*, finds use, because of its color. This varies from light verdigris-green to a deep blue-green. Uniform pigmentation proves most desirable. Early travelers from the Amazon, whence it derived its name, first brought amazonstone to Europe. Natives gathered it as pebbles from streams and used it in the shape of plugs which were passed through slits cut in their lower lips. The stone comes from a number of other places, always associated with granitic rocks and often with other gem minerals. Good crystals and masses occur in the Urals associated with topaz.

The region about Pikes Peak, Colorado, has become well known the world over as a source of large and beautiful crystals of this variety of microcline. With few exceptions the mineral appears here in granite cavities or pockets. Although the locality superficially appears most umpromising, large quantities of crystals abound. The coarse reddish granite of the district weathers rapidly into a gravel-like aggregate, and when the prospector finds fragments of crystals in the *débris*, he seeks the original cavity from which they came. These cavities assume all shapes and sizes and yield varying quantities of the mineral, a single one having been known to yield more than a ton of crystallized specimens. Crystal Park, lying from two to four miles south and southwest of Manitou Springs and extending southeasterly from the east side of Cameron Cove along the slopes of the mountains for a distance of three miles, yields a prolific supply of the stone in well-formed crystals of variable sizes. Associated with it is much microcline lacking the green color essential to true amazonstone, the crystals being usually of a light-gray, pink, or flesh color. Crystals of quartz also abound, usually the smoky variety but more rarely white or colorless (Plate 66). Often much flat white feldspar (albite) lines the cavities or attaches to the base of the amazonstone crystal. Fluorite, biotite, columbite, goethite, hematite, and a few other minerals likewise often occur in association. Groups of matrix with attached crystals of considerable beauty frequently are found in collections. The Canfield collection, in the National Museum, possesses one of the largest crystals known, some six inches in diameter.

The color of the Colorado amazonstone, while often of an intense shade, does not please as much as that of the mineral from Amelia, Virginia, and is often streaked and uneven in its distribution. Especially unfortunate is the fact that the best color often forms a thin zone about the exterior, covering an inferior shade in the central portion. Amazonstone abounds at the mica mines of Amelia, Virginia, where it occurs in a coarse pegmatite associated with other varieties of feldspar. Although massive and not in large and freely developed crystals as in Colorado, it possesses a pleasing and uniform shade and is better suited for cutting into beads and other ornamental forms. Material from these mines goes to Europe for cutting. (Plate 71, Fig. 3.)

Perth, Canada, yields a fine bluish-green stone, streaked with white, called microcline perthite; while Rockport, Massachussetts, Paris and Mount Desert, Maine, and Valhalla, New York, all produce ordinary green amazonstone.

A second variety of feldspar showing lively red metallic reflections in a white background has been called *sunstone*. This effect results from the presence of numerous small, thin plates of the oxide of iron, hematite, arranged in parallel orientation, so that when turned the stone reflects the color from these small plates. Rarity gave sunstone considerable popularity at one time, but it lost

PLATE 66

Amazonstone and Smoky Quartz. Pikes Peak, Colorado

that asset when a number of localities yielding abundant quantities appeared, especially at Tvedestrand in Norway. Among American localities may be mentioned Statesville, North Carolina; Amelia, Virginia; Fairfield, Middletown, and Media, Pennsylvania. Oligoclase usually and orthoclase sometimes supply the feldspar matrix for the small hematite plates. A similar variety from Modoc County, California, shows small plates of copper in a clear, transparent feldspar.

People, no doubt, know moonstone best of all the feldspars. The stone ranges from highly translucent to almost opaque and shows a beautiful pale-blue chatoyancy comparable, without undue poetic license, to moonlight. The finest stones come from Ceylon, where the rough mineral occurs in lumps of clay which presumably result from the weathered mother rock. Similar stones, some of which equal the finest from Ceylon, have come from the mica mines of Amelia, Virginia, where they are found with other varieties of feldspar, notably the beautiful green amazonstone already mentioned. Much of the moonstone from this locality, however, while possessing the blue sheen well developed, lacks the translucency of the Ceylonese mineral. In a number of places in the western part of the United States and in Mexico, the lavas carry small crystals of orthoclase which show the blue chatoyancy of moonstone to a high degree, but the material comes in grains too small for use as gems. Mineral Hill near Media, Pennsylvania, and Macomb, New York, also yield moonstone.

Of high rank among the very beautiful feldspars is *labradorite*, namesake of Labrador, where it originated. An extraordinarily lively display of color of a metallic, iridescent tone, that can best be compared to that of certain tropical butterflies or the reflection from the king feathers of a peacock's tail, characterizes this mineral. Turning it to catch the reflected light at varying angles will cause the dull-gray stone suddenly to flare into glowing color, which, upon continued turning, as suddenly disappears. Although polishing intensifies this effect, it is strikingly vivid on natural cleavage surfaces of the rough mineral. These colors vary from blue to violet, or are green, grading into blue on one hand and yellow on the other. Rarely the colors appear in tones of yellow, bronze, or red. These effects do not appear in small patches as in the opal, but in large areas, often covering the entire cleavage surface with a single broad blaze, usually of a more or less uniform shade. A Moravian missionary discovered the Labrador mineral during the latter part of the eighteenth century and it reached Europe as early as 1775. A number of places along the coast produce it, notably Nain and the adjacent Island of Paul.

Other localities have produced some labradorite but none equal Labrador in abundance of yield or in quality. At Keeseport, New York, a labradorite-bearing rock is quarried as a building stone under the name of "Au Sable granite." Dr. George P. Merrill described something of this sort in Moscow:

> The Church of Our Savior in Moscow has the audience room sheathed for a height of some 3 or 4 feet with a coarse dark gray feldspathic rock . . . which, like the labradorite of America, shows large purplish iridescent spots. As one passes along the somewhat dimly lighted room these spots shine out with wonderful beauty and then again disappear as the angle of vision changes. The effect is excellent. . . . The stone is said to have come from Kiev in the southwestern part of European Russia.[12]

Madagascar yields a remarkable stone of the feldspar group in a transparent, pale-yellow variety of orthoclase. This is nearly colorless and sufficiently clear to allow cutting into faceted forms, yielding a unique and very beautiful stone. The mineral, however, has too pronounced a cleavage and lacks sufficient hardness for commercial use as a gem.

[12] George P. Merrill. Stones for Building and Decoration, p. 116.

MYSTICAL PROPERTIES

Feldspars offer little, apparently, to excite the imagination. According to Pliny, the image shown by the moonstone waxes and wanes according to the period of lunar motion. During the period of the moon's increase the stone is a charm; during the waning the wearer is enabled to foretell the future. Carried in the mouth it becomes an aid to memory; as a powder and amulet it was prescribed in cases of epilepsy.

Amber and Jet

Amber appears far back in history. It supplies a subject for ancient myths and legends. It has been found with prehistoric remains in Egypt, Greece, Italy, and other lands. The Phoenicians made their way up the Atlantic coast of Europe not only for the tin of Cornwall, but it is believed for the amber of the Baltic Sea as well. The Greeks called it *elektron*, or sunstone, both because of its sunny color and because of its solar origin.

Amber is a fossil resin which, because its chemical constituents vary largely, science believes to have been derived from various species of extinct trees. That from the Baltic comes from a species of pine which grew abundantly along the shores of the sea during the Miocene geological period, several million years ago. Subsequently the sea invaded this forest and entirely submerged it. The waves have since washed up much of the amber, though it also abounds in place in sands characteristic of the sea bottom.

The physical properties of amber much resemble those of other resins. It is always amorphous, never crystallized. The pieces take numerous shapes, usually irregularly rounded but often in the form of icicles, drops, and others such as a viscous liquid might assume. It has a very low specific gravity, equal to or slightly heavier than water. It will indeed float in salt water, a fact of use in distinguishing true amber from its many imitations. It is soft and can readily be cut with a knife, which renders it a favorite material for carving. Rubbing with a cloth induces a strong negative charge of electricity so that it will pick up small pieces of paper, a test often applied to detect true amber though it should now be used with some degree of circumspection, since some of the substitutes and imitations will act similarly. The yellow of amber comes in countless nuances, ranging from almost colorless to dark yellow and brown. Red is sometimes met with, while blue and green are very rare. Much of the yellow amber becomes red with age. Some shows a beautiful fluorescence, that is, the property of producing by reflection a different color from the mass of the material. Sicilian amber in particular is famous for this quality, many of the yellow stones showing sapphire-blue, pale-rose, and ruby hues. Amber also varies in clarity. The finest is clear and transparent and of wonderful limpidity. Cloudy pieces sometimes reveal clear and translucent portions like a swirl of water. Still others resemble goose fat in their uniform cloudiness.

At the period of the formation of amber, the mighty forests of northern Europe and even Greenland and Spitzbergen abounded in insects. From the viscid nature of the primitive amber, it might be expected that leaves, twigs, and insects would be caught and held in it. In fact amber supplies an extraordinary record of the life of these ancient times, long-extinct species of bees, ants, spiders, flies, and even cockroaches having found therein "both a Death and Tombe." These unusual pieces are shamefully counterfeited by artifically embedding small, sometimes brilliant insects. This regrettable practice seems to date quite far back, for Leonardus, writing in 1750, reports such deceptions.

At the present day the amber of commerce comes almost wholly from the shores of the Baltic Sea. Its original home is a stratum of dark earth, greenish-blue in color from the presence of much "greensand," and called "blue earth." This stratum extends out from the land beneath the sea, and from it the winter storms tear loose the amber, enabling it to be gathered along the beach; or the floating masses of seaweed, called *kraut*, may be seined, brought to land, and any intermixed amber nodules retrieved. Most of that now produced is recovered by means of shafts driven through the clay to the amber-bearing blue earth, from which tunnels are driven in all directions. The crude material is washed in revolving barrels, scoured with brushes to remove the clay, and the amber floating to the surface is skimmed off and carefully graded.

The amber of Sicily comes from the eastern and southeastern coasts, most frequently occurring in small pieces found on the surface of the ground, in the furrows of the fields, or along the beach about Catania and Licata, where it is borne by the Simeto and Salso rivers. Little is now produced, no systematic search being made for it, although many think the Sicilian amber in many respects superior to that of the Baltic.

Burma produces abundant amber from clays in the Hukong Valley not far from the jade mines. Its pale cherry-red color costs it the favor of all save the natives of the country. Roumania also produces some amber but not abundantly.

Amberlike resins have been found in small quantities in the greensand formations of New Jersey and at Gay Head, Martha's Vineyard, Massachusetts, but in quality of mineralogical interest only. Material of good grade is known from but one locality in North America, the exact location of which remains a mystery. Natives of southern Mexico often bring it to the coast reporting it as so abundant in the interior that they use it to make fires. The rich golden brown of the Mexican product often shows a fluorescence, in this respect resembling the finest Sicilian amber. Undoubtedly a valuable deposit lies somewhere in the wild tropical belt of southern Mexico.

Many of the ancient philosophers recognized amber as a tree resin, a fact acknowledged in many of their myths and legends, though some believed it to be of solar origin, generated directly by the rays of the sun. A Greek legend dealing with amber, quoted from Buffum,[13] is given below:

> The Heliades' legend . . . recounts the adventures of Phaëthon, the favorite child of the Sun-god Helios, and his death in a rash attempt to drive the horses of the chariot of the sun which his father, yielding to his entreaty, had intrusted to him for a day. Phaëthon, disregarding the injunction not to whip the fiery animals, was seized with dizziness and terror on the height, and losing all control of the flashing steeds, approached the earth too near and set it on fire. At the earnest entreaty of the goddess Earth, who feared to be consumed, Jupiter launched a thunderbolt at Phaëthon, who forthwith fell into the Eridanus. The naiads of the stream buried his body on the shore, whither it had been washed by the foaming waves. His sisters, the Heliades . . . accompanied by their mother, the beauteous Klymene, a daughter of Oceanus, at last found the tomb of their brother. They remained beside it, weeping bitterly, and became rooted to the spot; and, as the penalty of assisting Phaëthon in yoking the steeds to the chariot, and encouraging his adventure, were changed into trees from whose branches tears continually fall. These tears, Ovid adds, are hardened by the heat of the sun and become amber, which the beaming river receives and sends to the Roman ladies for their adornment.

Jet is a variety of lignitic coal, and while it cannot be considered a mineral, its use as gem material entitles it to some consideration here. Jet, like coal, is derived from wood through a process of incomplete carbonization. Its hardness and black color made it at one time a favorite for certain kinds of jewelry, but the demand has largely passed. The chief source has been the beds of Liassic lignite in Yorkshire, England. Utah has within a few years yielded material of good quality.

[13] The Tears of the Heliades, or Amber as a Gem, by W. Arnold Buffum, 1900. To this entertaining little volume the author is also indebted for a part, at least, of the subject matter here presented.

MYSTICAL PROPERTIES

The belief in the curative properties possessed by amber persists to the present day. As late as 1862, King, in his *Natural History of Gems*, writes:

> That the wearing an amber necklace will keep off the attacks of erysipelas in a person subject to them, has been proved by repeated experiment beyond all possibility of doubt. Its action here cannot be explained, but its efficacy as a defence of the throat against chills is evidently due to its extreme warmth when in contact with the skin, and the circle of electricity so maintained; which latter, indeed, may account for its remedial agency in the first case.

Jet was believed to dissolve spells and enchantment. Burned as an incense, or bruised in water and taken internally, it served as a cure for various ills.

Coral

Coral, like amber, does not come within the definition of a mineral, but again its wide use for gem and ornamental purposes makes it worthy of consideration here. A simple marine organism, the coral polyp manufactures a calcareous or bony growth for its protection and habitation. Many species of coral polyps exist, each of which builds its support in a characteristic form. Some branch like shrubs, others spread out fanlike, or assume the appearance of flowers. The precious coral is a red form, branched and twigged like a tree and known scientifically as *Corallium rubrum*. It is limited to the Mediterranean Sea and comes largely from the shores of Africa and Italy. The color of coral varies from white through yellow to deep red. White and yellow varieties are rare and said to be the result of disease. The Italians call the highly prized pale flesh-red variety "*pelle d'angelo*" (skin of angels). Deeper reds are also common. Dead coral that has lain upon the sea bottom turns brown or black and is then called burnt coral. The chief constituent of coral is carbonate of lime, with some carbonate of magnesia and iron present, which last constituent accounts probably for its red color.

Coral occurs not as single individuals but in colonies or "banks," attached to the sea bottom, using rocks or other permanent objects encountered for supports. The most important areas stretch along the Algerian-Tunisian coast and about the islands of Linosa and Pantelleria, to the south of Sicily. The coral fisheries of Sardinia and Corsica also yield important quantities. Sometimes divers recover coral from shallow beds, but dredging forms the general method of production. For this purpose are used two timbers in the form of a cross, weighted by a large stone or by lead. Nets woven of coarse hempen cords are attached to the arms. When this is dragged over the coral bank, the larger pieces become entangled in the coarse, loosely woven ropes and the smaller ones are retained by the nets. The burning rays of the sun in that latitude make the work very arduous, for which the returns do not always compensate. The industry is chiefly in the hands of Italians.

Coral serves for beads and similar ornaments. Some of the larger pieces are carved, an art in which the workmen display great ingenuity, the irregularities of the material being cleverly turned to advantage.

In the Indian Ocean a black coral with a horny instead of a calcareous base is found, bearing the scientific name *Antipathes spiralis*. Some of the eastern countries prize it highly. A blue coral grows along the Kamerun and Gold Coasts of Africa.

The Greeks and Romans knew precious coral. The Greeks called it *gorgeia* and believed that it originated from the blood which dripped from the head of Medusa and, becoming hard, was planted by sea nymphs in the sea.

MISCELLANEOUS MINERALS

A number of minerals show pleasing or bizarre effects in their cut and polished form, but have for various reasons found only limited use as gem stones. Their very

PLATE 67

Titanite (Sphene). Isaac Lea Collection, National Museum

rarity in some cases has mitigated against their use. Others, possessing great beauty, lack durability; while still others must compete with their more striking brethren. A few of these only will be mentioned here.

Titanite: Sphene

A stone that surpasses the diamond in fire but can not compete with it as a gem because of the softness of its substance, is *titanite*, a silicate of calcium and titanium. When pure it is colorless, white, or gray, but small amounts of iron, manganese, or other metals impart a brilliant yellow or yellow-green color. It possesses a high index of refraction and its dispersion of light is extreme, so that a well-cut stone scintillates with flashes of color. A matched series of sixteen stones, in the Isaac Lea collection in the National Museum, forms a rare combination (Plate 67). The mineral occurs in metamorphic rocks throughout the Appalachian region of the United States, but rarely in a form suitable for cutting. A number of clear crystals yielding brilliant gems have been found at the old Tilly Foster iron mine near Brewster, New York. Other fine gems come from the Tyrol.

Euclase

Euclase, because of its rarity, seldom appears outside of large collections. It resembles the aquamarine and like it is chemically a silicate of beryllium and aluminum. The color of the stones never varies from a delicate tint of blue and green. Only two localities have yielded gem material: the state of Minas Geraes, Brazil, where it occurs in a schistose rock associated with clear yellow topaz; and in gold placers of the Sanarka River in the Urals. Cut gems of this mineral are not large, seldom exceeding five carats in size although some large rough crystals have been found in Brazil. A large clear crystal in the Roebling collection of the National Museum weighs over four ounces, and some have been reported weighing over one pound.

Phenacite

Phenacite, another of the beryllium silicates, differs from euclase and the beryls in its lack of color, although occasionally it bears a slight rose or brown tint. Since it resembles many of the commoner colorless stones it rarely finds use as a gem, though its dispersive property is more marked. Brazil also furnishes the finest examples of this mineral. Large stones likewise occur with the emerald and the chrysoberyl at Takowaja in the Urals. Very fine small crystals are found at Mount Antero, near Pikes Peak, Colorado, and at Bald Mountain, New Hampshire.

Rhodonite

This is a massive stone of beautiful rose-red color, hence its name from a Greek word meaning *rose*. It is well adapted for beads and small ornaments. Various points in New England, as Blue Hill Bay, Maine; Cummington, Massachusetts; and Cumberland Hill, Rhode Island, yield rhodonite. Delicately colored material also occurs in California at Happy Camp, Siskiyou County; Taylorsville, Plumas County; and Lemon Cove, Tulare County. The best material comes in abundance from the Urals. Very large masses are sometimes quarried from these deposits and it is said that the sarcophagus of one of the Czars of Russia is carved from a single block of the mineral. (Plate 68, Fig. 9.)

Vesuvianite

A complex silicate of calcium and aluminum, *vesuvianite* is mentioned here for the reason that a bright, lustrous green variety found in Tulare and Siskiyou Counties, California, and by virtue of this fact known as *californite*, has been utilized in the making of small ornaments which are often sold to the unwary as jade. The color varies from bluish to yellowish green and is translucent. An apple-green variety has proved particularly attractive.

Semi-precious stones

1. Obsidian. 2. Thomsonite. 3. Jasper. 4. Calamine. 5. Fossil wood. 6. Turquoise. 7. Fossil wood. 8. Turquoise. 9. Rhodonite

The mineral occurs in a region of greenish-gray to black serpentinous rocks which have been badly crushed by earth movements so that nodules of the vesuvianite seldom exceed a few inches in diameter.

Thomsonite

This somewhat freakish-appearing mineral, an aluminum, calcium, and sodium silicate, occurs in gem varieties only as filling amygdaloidal cavities in trap rocks. The prevailing form is a spherical concretionary flesh-pink mass with white, greenish, and nearly black concentric zones embedded in it. The mineral takes a high polish and makes a very attractive gem of the souvenir class. It has been found in considerable quantity in the beach gravels resulting from the breaking down of the trap rocks of Lake Superior near Grand Marais, Cook County, Minnesota. It is cut chiefly *en cabochon* and as beads. Rounded pebbles of greenish chlorastrolite and zonochlorite often occur under similar conditions and are used in like manner though of less striking appearance. (Plate 68, Fig. 2.)

Cyanite

Cyanite occurs in long thin-bladed forms, often of a beautiful sky blue, in schists and gneisses. It has a very perfect cleavage and therefore splits up readily into thin folia, which show an odd peculiarity in hardness. Tests on the broad, flat cleavage surface in a direction perpendicular to the length give a result of about 7 of the hardness scale, but in the direction of the length, of only 5. The pronounced cleavage precludes the use of the mineral for gem purposes.

Malachite and Azurite

Both of these minerals—hydrous carbonates of copper—are secondary, and result from the decomposition of the primary copper sulphides through surface waters, the sulphur being lost or carried away in the form of a soluble sulphate, while the copper combines with carbonic acid to form the two minerals. Malachite has a characteristic green color and has lent its name to a common dye of a similar color—malachite green. Azurite, as its name implies, is blue, most frequently azure blue, in color. Malachite assumes variable forms, most commonly massive, and is sufficiently hard and free from defects to allow of its being cut into sheets and used in ornamental work. Such work almost invariably takes the form of a veneer of small thin pieces so closely joined as to give the appearance of a continuous sheet. The typical malachite is botryoidal in form (*i.e.*, having the appearance of a bunch of grapes) and when cut shows concentric bandings of slightly variant colors like the agate. Azurite and malachite sometimes occur together in alternate bands as shown in Plate 69. Both minerals may occur in true crystal form, though the malachite does so less commonly. Since they are products of alteration by surface waters, it naturally follows that the deposits of either mineral occur superficially, and as the mines grow deeper the carbonate will disappear and only the original sulphide remain. The copper mines of Arizona produced at one time great quantities of the copper carbonates, but have now reached a depth below the zone of oxidation and yield only sulphides. Russian copper mines have for many years furnished a large share of the malachite of commerce, that from the Arizona and other mines occurring in small velvety masses and disseminated forms not suited for commercial veneering. The mineral is rather too soft for jewelry, though sometimes so used. The industry is largely confined to Russia.

Calcite: Carbonate of Calcium

None of the forms in which this mineral occurs can be considered as gem material in the accepted sense. But if beauty be a sufficient criterion, many varieties among

Malachite and Azurite, Bisbee, Arizona

them will justify stretching a point and the devotion of a few lines to their consideration. Calcite, or calc spar, crystallizes under a variety of forms, to which varietal names are given. *Nail-head spar* identifies crystals the terminations of which resemble the head of an old-fashioned wrought-iron nail; *dog-tooth spar* refers to sharply pointed forms like a dog's tooth; *Iceland spar* includes the beautifully clear, doubly refracting forms from Iceland used for optical purposes and figured on Plate 70; *flos ferri* (flower of iron), stalactite, stalagmite, chalk, limestone, and common marble are but varietal forms of the same mineral in a condition of more or less purity. The name *satin spar* applies to a compact but finely fibrous variety sometimes used in small ornaments. The highest grade of statuary marble is but an aggregate of small irregular calcite granules. For many years a calcite species of fossil coral (*Acervularia davidsoni*), from the Devonian beds of Iowa, has been cut and polished and used largely for paper weights and local souvenirs.

No more beautiful forms of the mineral occur than the two erroneously grouped under the names *onyx* and *Oriental alabaster*. Onyx proper is a variety of chalcedony; and alabaster, of gypsum. The misnamed stones are forms of calcium carbonate deposited from solution in rifts and caves of limestone areas or by springs in regions of dying vulcanism. The cave deposits, like the stalactites and stalagmites which form so interesting a feature of the caves, take as a rule a white or light amber color, with wavy bandings due to the mode of growth. So far America has found but little use for this material. The ancient Egyptians, however, utilized it in the manufacture of "alabastrons" for holding the ashes of the dead, and for small household articles, as well as for statues. The variety deposited by springs, presumably hot, reveals a more variegated color, greens and reds predominating. The so-called Mexican onyx used for the tops of stands, soda-water fountains, and the like, is of this type.

Deposits of the material near Prescott, Arizona, have been utilized of late in the manufacture of small spheres terminating the gear-shift of automobiles. The most noted deposits occur, however, in Mexico, both on the peninsula and mainland.[14]

Staurolite

This mineral scarcely belongs among the gems, though its form, in part artificial, yields itself to decorative purposes. Chemically a hydrous silicate of aluminum and iron, *staurolite* is opaque and of a prevailing brown color. Its interest lies wholly in its cruciform or star-shaped crystals, which, when well developed, can with the aid of a file or other abrasive instrument be wrought into forms suitable for use as charms. The mineral occurs abundantly in certain crystalline schists in Virginia and Georgia, and being somewhat refractory under normal conditions, remains among other *débris* when the mother rock weathers away.

One legend concerning these "fairy stones" relates that "when Christ was crucified, elfin messengers carried the news to all parts of the world. When the tidings reached the fairies in the far-off rugged mountain regions they ceased their merrymaking and at once began to make these crosses as mementos of the sad event."

Pyrite

Pyrite, a sulphide of iron, crystallized in the form of cubes or some of their modifications, is hard, brittle, and of a lustrous brassy-yellow color. In neither color nor hardness does it resemble gold, yet strangely enough so frequently do men mistake it for that metal that it has earned for itself the soubriquet of "fool's gold." It may occur in rocks of any kind and in all geological horizons.

[14] See Geo. P. Merrill. The Onyx Marbles: their Origin, Composition and Uses, both Ancient and Modern. *Rep. U S. Nat. Mus.*, 1893, pp. 539-585; also Stones for Building and Decoration, (Wiley and Sons) New York.

Sometimes it bears precious metals; sometimes it occurs in large masses and is mined and roasted for the manufacture of sulphuric acid. In clustered or isolated crystal form it has beauty and fills an important place in most collections, though its abundance makes it cheap. When finely crystallized on flat surfaces it is sometimes used as a cheap gem mineral under the name "sulphur diamond."

Hematite

Hematite, the natural oxide of iron, abounds as a mineral, occurs in a great variety of forms, and has many technological uses. As a gem mineral, however, it finds but rare employment, largely because of a lack of transparency, a too somber color, and a high specific gravity which renders it too heavy for use in beads or similar forms. Cut stones show a velvety dark-red to black color, usually with a metallic to semimetallic luster. Material suitable for cutting abounds in many parts of the United States, especially in the iron mines of the Lake Superior region of Michigan. A form from this region is associated with dark-red jasper in alternating bands which give a unique and pleasing effect when cut into small dishes and other objects.

MINERAL AGGREGATES: ROCKS

The distinction between mineral and stone or rock does not always appear plain to the popular mind. Indeed, no real difference exists, other than that sanctioned by common usage. The same elemental materials compose both, but the term *mineral*, as already stated, by convention covers substances possessing definite physical, chemical, and crystallographic properties, while the terms *stone* and *rock* include less definite bodies, although perhaps composed of the same substances. Ordinary white marble, though commonly described as a stone, is an aggregate of calcite particles with or without an admixture of other minerals. Granite, on the other hand, consists of two or more minerals, principally quartz and feldspar, with perhaps mica and other minor constituents. Naturally then, rocks occur in larger masses and are for the most part less suited for the purposes we have been discussing.

Many of these mineral aggregates, however, call them rocks, stones, or whatever one wills, possess characteristics of color and texture which make them eminently desirable for ornamental work and the higher grades of architectural construction. It will be worth while to consider these briefly, though the subject itself deserves a volume.[15]

The Marbles

No exact definition for this word exists, dictionaries to the contrary notwithstanding. Basing our definition on world-wide usage, we may say that a marble is a stone composed essentially of carbonate of lime and magnesia possessing such qualities of color, texture, and perhaps markings as to render it suitable for works of art, decoration, or the higher grades of architectural construction. Yet this limits the word unduly. The green marble, popularly called *verd-antique*, is an impure serpentinous rock, while the *marmor lacedoemonium viride* is a porphyritic diabase, an igneous rock. Chemically no distinction can be drawn between rocks known simply as limestones and those called marbles. A compact neutral-colored stone, which the Census of 1880 unhesitatingly tabulated as a limestone, has now, with the gradual change in taste, entered the market as a marble. The Italian travertine, which has for many years been imported as limestone, without question, has now become the subject of a customs fight, because American dealers would classify it as a marble for no other reason than to have it subjected to a higher duty in order to "protect" the

[15] Geo. P. Merrill. Stones for Building and Decoration, (Wiley & Sons) New York, 1891, 1897, 1903. Appendix IV gives a bibliography of the subject.

PLATE 70

Iceland spar. Illustrating double refraction

domestic output. Disregarding all this, we shall adhere to the definition given and consider here as marbles the calcareous and magnesian rocks possessing the essential qualities mentioned.

The marbles of the eastern United States are limited largely to Vermont with lesser areas in Massachusetts, Connecticut, New York, Maryland, Georgia, and Tennessee. Those of Vermont are largely lime carbonates of white, blue-gray, variegated, and cream-tinted types, though a dense chocolate-red dolomite (carbonate of lime and magnesia) occurs in the region of Lake Champlain. The white, blue-gray, and variegated types have remained for many years the best known of American marbles. The marbles of Massachusetts, Connecticut, New York, and Maryland are largely dolomitic and used chiefly for architectural purposes. The Georgia and Alabama materials are again lime carbonates differing mainly in texture and degree of whiteness. A coarse stone of pleasing pink color comes from Georgia. Of a wholly different type as regards both color and crystallization is the marble of Tennessee which varies from a dense, fine, even-grained stone, of pinkish-gray to rose-pink color, to coarsely variegated forms somewhat resembling that of Lake Champlain, New York. It is, however, a limestone and not a dolomite.

Until a change in public taste brought with it a change in name, the entire area of the Mississippi Valley produced no marbles. Now a light-drab "limestone" from Missouri, in texture not greatly unlike that of the Tennessee marbles, finds much favor for interior work. The only marbles of the region west of the front range of the Rocky Mountains that have thus far become prominent are those of the Yule Creek region in Gunnison County, Colorado. The stone here consists of a lime carbonate of a beautiful clear whiteness and fine grain, unexcelled in quality, but difficult of access and remote from the market. The Lincoln Memorial in Washington is constructed of this material. Alaska has not as yet had her resources sufficiently explored for complete knowledge of them, but a white, variously clouded and veined stone of high grade from the Wrangell Island region is now being produced by Vermont quarry companies.

Of all the purely decorative marbles none has shown more pleasing colors and configuration than the miscalled onyx, best known commercially as Mexican onyx. The true onyx, as noted elsewhere, is a variety of chalcedony. The onyx marble is a calcareous rock, like the travertine of Italy, a product of deposition by hot springs. To this mode of origin it owes its banded structure and translucency. Stones of this nature occur near Prescott and Phoenix, Arizona, to a limited extent in California, in Mexico proper, and at New Pedrara, about half way down the peninsula of Lower California. The colors run from green to a cream tint, often beautifully veined. Unfortunately poor taste in its use and in its adoption for drug-store and bar-room counters has brought this stone into discredit. Of the same general nature but of a cream-white to almost golden-yellow tint are the stalactites and stalagmites in our limestone caves, particularly throughout the southeastern States. In composition, mode of formation, and general aspect, these resemble identically the Egyptian "Oriental alabaster." The name constitutes a misnomer since this stone is a very pure calcium carbonate while true alabaster is a variety of gypsum, a sulphate of calcium. No serious attempts have been made to utilize this stone in America. The Egyptians used it in the manufacture of their "alabastrons" (hence the name), various articles of the toilet, and even statues. An occasional pedestal of foreign manufacture for a bust or statue may be found in our art galleries, but nothing else. A most singular illustration of the misuse of the material is offered in a Virginia cemetery where it has been made into tombstones.

As a whole, coarser crystallization characterizes the

American marbles in comparison with many of the imported varieties. None of the domestic quarries produces a dense, close-grained stone like those of Siena, Italy, or of northern Africa, nor highly brecciated varieties like those of Gragnana and Seravezza in Italy.

Gypsum: Alabaster

Gypsum is a hydrous sulphate of calcium, snow-white when pure, but often colored and clouded in all shades of gray. The white, compact variety constitutes the alabaster of commerce, so generally used for carvings in statuettes and smaller works of art. It is too soft for use where subject to wear, and soils too readily to make it desirable material where exposed to handling or the weather. A compact but finely fibrous silky variety, known for its luster under the name "satin spar,"[16] supplies a favorable material for the manufacture of souvenirs, and is at times even cut into beads, though their softness renders them short-lived. The common commercial variety occurs in beds sometimes of great thickness and extent, and is used as a land plaster or in the manufacture of plaster of paris. It often crystallizes in giant crystals which have a pronounced cleavage parallel to one of the faces, yielding beautiful transparent folia. The untrained mistake it for mica, from which, however, it may be distinguished by its softness and the elasticity of the folia. The pale, soft color of this form led the mineralogist Wallerius to name it *selenite*, from a Greek word meaning "moon."

MYSTICAL PROPERTIES

Alabaster, according to Leonardus, serves best for vessels to hold unguents, as it preserves them without spoiling. Dioscorides and many other doctors of antiquity accounted it good in medicine. He who carried it would prove victorious in suits-at-law. It is doubtful whether

[16] A fibrous variety of calcite passes under this same name.

the material here referred to was not the so-called Oriental alabaster, a carbonate of lime.

Serpentine

Like calcite, serpentine can scarcely be considered a gem or a precious stone; nevertheless, in some of its phases it surely displays sufficient beauty to merit attention here. Of a prevailing greenish color, variously streaked and mottled, the ancient world used serpentine, calling it *verd-antique marble* whatever its source. The name serpentine derives from the Latin *serpentinus* (serpentlike), presumably because of its spotted colors which range through gray-green to bright green, yellow, and black, sometimes spotted with red. The stone is of close texture and is used extensively as a marble. It requires care in production and handling owing to the only too numerous dry seams which traverse it and which result from its origin through oxidation and hydration from a massive igneous rock. Properly used, it adapts itself well to certain forms of interior decoration, though the green color is necessarily cold and needs to be used with discretion.

Widespread in its distribution, the stone occurs in greater or less abundance in all of the Appalachian States, and to an as yet unknown extent in the areas west of the front range of the Rocky Mountains. Small deposits render many occurrences of little consequence; the small amount of desirable material in some large deposits decreases their value, as is the case with the williamsite variety in Pennsylvania. Roxbury, Vermont, produces a beautiful deep-green stone mottled with dark blotches and white veins and streaks, which finds extensive use for interiors and facings of business houses. This is probably the most widely known of American serpentines, and, with the possible exception of some Pennsylvanian and Maryland occurrences, the only one that competes in our market with the imported Italian material.

Connecticut has at Milford what have been described as extensive deposits of which unsuccessful attempts at exploitation have been made. The description lists this as a bluish-gray or dove-colored limestone clouded with greenish-yellow serpentine, the disposition of the colors being cloudlike, flawed, or veined. Massachusetts possesses many localities capable of producing small blocks of good color, that of Westfield in Hampden County alone being worked on a commercial scale. The rock has a deep green color with interesting radiating areas of a darker hue due to the presence of an amphibolic mineral. At Moriah and Port Henry in Essex County, New York, exist deposits of serpentine limestone that, though now inactive, have in times past been worked as marbles. Near Easton, Pennsylvania, lies a very interesting serpentinous rock, sold on the market as *verdolite;* and in the old chrome mines in the southern part of the State have been found many small masses of a deep-green, highly lustrous variety known as *williamsite.* This has been utilized to some extent for small ornaments and even beads, slightly simulating jade. In Lancaster and Montgomery counties, Pennsylvania, and adjacent portions of Maryland, particularly in Hartford County, occur deposits of green, coarsely variegated varieties which, in connection with those of Roxbury, Vermont, furnish a counterpart of the Italian stone. At Montville, New Jersey, a beautiful oil-yellow stone, suitable only for small ornamentation, is found in small masses. Holly Springs, Georgia, yields a compact deep-greenish variegated stone which is utilized as a verd-antique marble. What the western States have to be developed must be decided later. Near the Great Bend of the Gila River in New Mexico there occurs a narrow bed or dike of a peculiar banded serpentinous deposit which was at one time on the market as *ricolite*, so called from the Spanish word *rico* (rich), in allusion to its deep green color.

A very considerable portion of the serpentinous marbles now in use in America comes from Italy and Greece. The Lizard district in southern England, however, produces one of the most noted of the foreign serpentines. The stone varies from grayish to deep green, often red- and green-spotted, and is admirably suited for ornamental columns, bases for statuettes, and so on. In years past an attempt was made to work it as a marble for general interior use but the jointing so characteristic of the stone caused its failure. Scores of private individuals in the nearby locality now work it up into small objects of more or less artistic quality.

The Chinese work a very dense compact serpentinous rock known as *Yu Yen* into small objects, many of which are sold as jade.

Granite

The granitic rocks are better suited to the more massive forms of architectural work than for purely decorative effects. Nevertheless, many of them, owing to color and structural features, may be utilized to advantage. Indeed, a peculiar varietal form occurring in small joint blocks in the mountains of Virginia and North Carolina, known as *unakite*, has been used in *cabochon* forms quite effectively. (Plate 71, Fig. 9.) The stone comes in a beautiful pink, mottled with green and speckled with black. Certain of the Maine granites show large porphyritic crystals of light flesh-pink orthoclase embedded in the finer gray ground. The pink, green-spotted granite of Milford, Massachusetts, or that of Stony Creek, Connecticut, with its wavy bands of varying hues of pink and gray, are well adapted to interior as well as exterior uses and may properly be classed as ornamental. The form of pegmatite known as *graphic granite*, though lacking in color, possesses a unique characteristic in a letter-like figuration. The so-called porphyries, like the *rosso antico* of Egypt, are prominently developed in many parts of the country. Those of eastern Massachusetts and

PLATE 71

Semi-precious stones

1. Fossil wood. 2. Sodalite. 3. Amazonstone. 4. Variscite. 5. Jasper. 6. Tiger-eye. 7. Chrysoprase. 8. Variscite. 9. Unakite. 10. Lapis-lazuli. 11. Malachite

the Franconia region of New Hampshire show a deep jasper-red color spotted and mottled with lighter hues, and admirably serve for highly ornamental work. They are hard, tough, and consequently expensive to work; but with modern machine methods, their failure to find a place in the shop of the artisan, or in public and private galleries, must be assumed to be due only to a lack of appreciation and originality in taste. The rock *obsidian*, which is but a glassy form of lava essentially granitic in composition and known as rhyolite, often occurs in a brown-red color, variously streaked and mottled, which forms an admirable material for cutting souvenirs *en cabochon*, or even shallow saucer shapes for ash trays. Obsidian is said to have been discovered in Ethiopia and named for Obsius, its discoverer. The American aborigines used it as a favorite material for arrowheads and knife blades.

Porphyry

Those desiring oddities in the way of decorative stones might find them in the curious porphyry of Charlotte, North Carolina. The stone comes in a light grayish-white tone, penetrated in one general direction by long pencils of manganese markings. Cut at right angles, these appear as rounded spots of sizes up to a centimeter, but cut parallel, they appear as a black spraying or in dendritic forms. The stone goes locally by the name *leopardite*, and can lay claim to more interest than beauty. A second possibility from the same State is an orbicular diabase found in Davie County. This shows a pinkish feldspathic base with abundant concretionary masses of green augite, which, on a polished surface, appear as circular areas an inch or more in diameter.

Basalts and Rhyolites

A series of altered eruptive rocks near South Mountain and Chambersburg, Pennsylvania, presents most interesting phases of color and textural peculiarities, a green and red tone perhaps generally prevailing. The material, though hard, badly jointed, and obtainable in blocks of but very moderate dimensions, could yet be worked up to advantage, had one the necessary originality in taste. These rocks are described in detail by Geo. W. Stose in a report of the Pennsylvania Geological Survey.[17]

Jaspery Hematite

A unique stone for interior ornaments, urns, newel posts, and so on, is offered by a lean type of iron ore from the Ishpeming district of Michigan. The material consists of an admixture of deep blue-black hematite and red jasper, arranged at times in contorted alternating bands, and again as sharply angular fragments of jasper in the hematite. A 5-inch sphere of the latter type is on exhibition in the mineral hall of the National Museum.

[17] Mineral Resources of Adams County, Pa., *Bull. C-1*, *Penn. Geol. Survey*, 1925.

CHAPTER V

SYNTHETIC GEMS

The great value of precious stones has led man to exert every effort to solve the mysteries that surround their origin and to duplicate, if possible, the more valuable varieties. A synthetic gem is one prepared in the laboratory, and which, in its chemical and physical properties is identical with the natural stone. That man produces the one and nature the other, forms the only essential difference.

Naturally enough, the diamond, as the most valued and popular of all gems, first attracted interest in this field, and numerous more or less ingenious attempts to produce it have been made. The experiments of H. Moissan came nearest success, although the diamonds produced were barely visible to the naked eye. The experimenter obtained them by saturating molten iron with carbon at the temperature of the electric arc and plunging the molten mass into cold water. The mass of iron was then dissolved in acid and the residue subjected to the laborious process of extracting the diamonds with the aid of a microscope. Commercially, we are far from being able to produce artificial diamonds, and it may never become practicable.

Outstanding success has met the efforts in one group of minerals, that of synthetic rubies and sapphires. These are now manufactured on a large scale, one plant in Germany having a productive capacity of five million carats a month. The synthetic gems differ from the natural stones in such minor details that often the expert finds it difficult and the layman quite impossible to detect the difference. Verneuil devised the apparatus for producing these synthetic corundums. Finely ground alumina, the substance of the ruby and sapphire, is sifted upon a clay support which a blowpipe, burning a mixture of oxygen and hydrogen, heats to a high temperature. The particles fuse and gather together as a small drop which grows by accretion of fine dust from above. In this way a pear-shaped drop is formed, called a *boule* or *birne*, varying in weight from thirty-five to two hundred and fifty carats.

At first the manufacturers powdered fragments, rejects, and other undesirable natural stones, and reformed them into gems. These were called reconstructed gems. Now they employ chemically pure alumina, to which is added an appropriate amount of coloring compounds. To produce the ruby, chromium oxide is added; for the the sapphire, the oxides of iron and titanium. Green and yellow stones may also be produced, and by use of vanadium a stone somewhat resembling the alexandrite is formed. Spinels of a beautiful color may be obtained in the same manner.

In chemical composition and all physical properties, these synthetic gems are identical with those occurring in nature and may appropriately be called rubies and sapphires. It should be borne in mind by the prospective buyer that the corundum group supplies the only synthetic gems now commercially produced. The unscrupulous or ignorant sell them as synthetic emerald, or alexandrite, a decidedly fraudulent practice.

Synthetic rubies and sapphires can be obtained at prices varying from two to three dollars a carat. A natural ruby, on the other hand, may bring as much as three thousand dollars a carat. Fortunately for the ruby miner, many persons of taste and discrimination still prefer the natural stones.

CHAPTER VI

COLLECTIONS AND COLLECTORS

THE collecting habit is inborn and limited to individuals of no particular nationality or station in life. Though it may be cultivated, it seems in certain cases instinctive, and one cannot claim it even to be a purely human propensity, for we are told that certain birds, as the raven and the magpie, will steal and secrete objects for which they can have no possible use. In its various phases it includes a wide range of objects, manifesting an equally wide range in taste and purpose. The habit is controlled as a whole by no pecuniary motive since the objects accumulated may have no intrinsic value. We are told of one who had collected buttons until the number of individual kinds ran into hundreds of thousands. The objects of desire may be manuscripts, first editions, bric-a-brac, coins, meteorites, minerals, butterflies, or any one of a score of others which for the time being are desired, and perhaps for no reason but to gratify a momentary whim. Thousands of dollars are sometimes expended in securing an object the value of which depends only on its rarity. The collector may crave it not more for itself than for the fact that he may have something lacked by another. The extreme phases of the habit are exemplified on the one hand by the collectors of art objects, rare books, and manuscripts; and on the other, by the collectors of buttons already mentioned and of objects of natural history, material for which in the early stages of ingathering are of value measured only by the labor they have cost.

But whether or no the individual objects of a collection possess a value that may be expressed in dollars and cents is a secondary consideration. The real value in its indulgence finds expression in the relief afforded from monotony professional or business tasks, or a mental tonic and excitement incident to pursuit and acquisition.[1]

There is, moreover, in many cases a distinct esthetic gain, as when the growing collection is of materials such as to excite discriminative care and selection and, it may be, a knowledge of technique.

Of the hundreds of inviting fields open to the collector we can here consider but one—that of natural objects of the mineral kingdom, the varied shapes and colors, high indices of refraction, and consequent beauty of which have made them sought in some of their varieties by peoples of all nationalities and stages of civilization since time immemorial.

The true collector, it may be remarked, is not satisfied with mere perfection of crystal forms, their rarity or beauty; he must know their life history, as it were, the conditions under which they have originated and the transformations, if any, they may undergo. He will discover that quartz is one of the most stable as well as the most widespread of minerals; that it may occur in good crystalline form in the cavities and rifts, not only of granitic and gneissic rocks, but in sandstone, as at the noted Hot Springs region in Arkansas; in cavities of limestone, as in Herkimer County, New York; in slates, schists, and elsewhere. Beryls and topazes he learns to look for in the veins of pegmatite whence come our commercial supply of mica and feldspar. Tourmalines, green and red, he finds in these same veins only where the

[1] It is told of Prof. Geo. J. Brush that when worried and vexed over administration problems he would lay them aside and resort to his collection of minerals for relaxation. The late Secretary Walcott of the Smithsonian Institution would do the same with his collection of fossils, which he kept in a room adjacent to his office. Mr. F. A. Canfield would spend hours in the recreation of cleaning the matrix from a particularly fine crystal, and Colonel Roebling rarely let a day pass that he was not "at play" with his collection.

orthoclase has by chemical processes been replaced by albite. The almandine garnet is widespread as a constituent of schists and gneisses, while grossularite, or cinnamon garnet, is a constituent of limestone. Peridots are found in basaltic rocks and diamonds in peridotites.

He will learn also to distinguish between primary and secondary minerals—between those which form with the original consolidation of the rock and those which come in afterwards, as the zeolites and opal. Turquoise is not an original constituent of the rock where found, but as stated elsewhere, is a secondary product along zones of shattering and decomposition.

There are minerals, too, that are alteration products, as serpentine after olivine, and pseudomorphs, or false forms, such as are assumed by limonite altered from pyrite. All natural substances are susceptible to change under the changing conditions of heat and cold, moisture and dryness, and even the hardest and toughest of rocks will in time break down to clay and sand.

To derive the utmost satisfaction from collecting it is not enough that one remain at his desk and mail his orders from a printed catalogue. He with whom the taste is inborn will obtain his chief joy through the finding of things for himself. He will prowl among the stalls of dealers in old books; haunt the rooms of the auctioneer and other purveyors of "used" articles from dismantled households; or, if he be one of the elect of whom I am writing, the refuse piles of mines and quarries. He who has not himself unearthed, through perhaps hours of labor in soil and muck, some rare treasure to be added to his hoard, has yet to taste the supreme delight of his adopted calling. We know of a retired business man who finds congenial occupation in seeking out for himself interestingly colored or marked bits of minerals and grinding them into various forms and shapes such as when polished are entitled to consideration as gems.

The collecting of minerals is not to be regarded as wholly a hobby for the entertainment and diversion of the few. Recent advances in science and industry, particularly during and since the late war, have developed many uses for minerals heretofore little dreamed of; and in seeking sources of supply, existing collections have proved of inestimable value. This may be illustrated by the sudden demand during the late war for so common a mineral as quartz for various uses in connection with the transmission of sound, when collections the country over were ransacked for material of the desired quality. Beryllium, the essential constituent of beryl, is becoming of value in the construction of motors for aeroplanes, and an adequate source of supply may become an important problem. Pollucite, heretofore regarded as an interesting chemical compound, suddenly becomes of commercial value as a source of the element caesium for radio tubes; and the commonplace and heretofore little prized minerals, andalusite, sillimanite, and cyanite, are being utilized to give strength to the porcelain spark plugs in automobile engines. Hence it is that the larger museums have made strenuous efforts to build up their collections, and in so doing have sought far and near for new sources of supply.

The American Museum of New York, the Field Museum of Chicago, the British Museum, and the National Museum of Washington, as well as the museums of Harvard and Yale Universities and those of the Universities of Paris and Vienna, have been particularly active in this direction and have each accumulated many thousands of specimens of a value difficult to estimate or indeed to comprehend.

As has been noted, minerals not only possess a fascination for the collector on account of their variety of beautiful forms and colors, but they are of all natural history objects best adapted to his purpose on account of their comparative permanence and indestructibility under ordinary care. The fact that many of the less valuable varieties are of such color and physical properties that they may be cut and utilized as gems adds still further to their desirability, as already noted.

In this connection it is interesting to record that James Smithson (Plate 72), whose beneficence established the Smithsonian Institution, had formed what was for his time an important collection of minerals, comprising, presumably, a sample of the mineral *smithsonite*, which he had himself analyzed and which has been named in his honor by the mineralogist Beudant. This collection was brought to America and for a time was in the custody of "The National Institute," a local scientific institution of Washington.[2] Later it was transferred to the Smithsonian together with other collections on completion of its building, where unfortunately it was destroyed by fire in 1865. Nevertheless, it was this collection and others later acquired through the law[3] of 1880 that formed the nucleus about which has been built up—crystallized one might appropriately say—the magnificent collections of today.

According to S. G. Gordon of the Philadelphia Academy of Sciences[4] the earliest mineralogists and collectors in America were Adam Seybert (1773–1825); Thos. P. Smith (died 1802); Sylvanus Godon, who died about 1812; James Woodhouse (1772–1809); Gerard Troost (1776–1850); Lardner Vanuxem (1792–1848); Isaac Lea (1792–1880); Wm. Keating (1790–1848); and Thos. Nuttall (1786–1859). Seybert was the first scientifically trained miner-

[2] See G. B. Goode, Origin of the National Scientific and Educational Institutions of the United States, *Ann. Rep. S. I.*, 1897, Part II.

[3] In 1879, when most of the existing Government surveys, whose work included the collecting of specimens in the field, had been established, Congress deemed it important to practically reenforce the provisions of the act founding the Institution, in order that there might be no doubt as to the proper disposition of the material certain to be derived from these various sources, by the following enactment in the Sundry Civil appropriation act for 1880:

"All collections of rocks, minerals, soils, fossils, and objects of natural history, archeology, and ethnology, made by the Coast and Interior Survey, the Geological Survey, or by any other parties for the Government of the United States, when no longer needed for investigations in progress, shall be deposited in the National Museum."

[4] *American Mineralogist*, Vol. 4, 1918, p. 16.

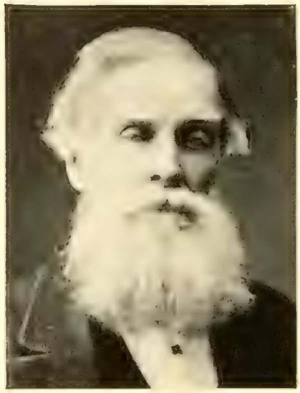
alogist and Troost, who had studied under the French mineralogist Hauy, the first crystallographer. The first mineral cabinet to be publicly exhibited in the United States was, according to G. B. Goode,[5] that brought from Europe in 1790 (Gordon says 1794) by David Hosack, the botanist and founder of the first American botanical garden. This collection passed subsequently into the possession of Princeton University where its identity became lost. Seybert's cabinet, the second brought over, has been kept intact in its original condition in the Academy of Natural Sciences in Philadelphia, where are also to be found those of Sylvanus Godon, above mentioned, and others of later date, as Thos. McEuen (1799–1873); Samuel Ashmead (died 1864); Geo. W. Carpenter (1802–1860); and W. S. Vaux (1811–1882). The last named, which was for its time one of the finest in America, has since been probably equaled by that of George Vaux, Jr., also of Philadelphia. Mr. F. A. Canfield in a pamphlet issued in 1923[6] enumerated 180 individual American collectors who had made, each, one or more collections which in later years passed over to public museums, universities, or back into the hands of dealers to be redistributed. Many of these collections were of a high order and of very considerable value from a monetary standpoint. A collection containing some 1,600 individual specimens made by Clarence S. Bement of Philadelphia was rated at the time (1890–1900) as the finest in America and one of the finest in the world. This was at the latest date mentioned sold to Pierpont Morgan and presented to the American Museum of Natural History in New York. Bement (1843–1923) was a wealthy manufacturer who turned to the making of collections as a recreation and spared neither time nor funds in pursuit of his hobby. Having followed one line as long as it furnished adequate returns, he would sell his collection and

[5] Op. cit.

[6] The Final Disposition of Some American Collections of Minerals. (Privately printed.)

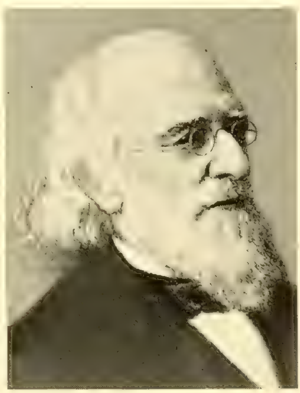
James Smithson, founder of the Smithsonian Institution

1



2

3



4

(1) C. S. Bement; (2) W. S. Vaux; (3) George Vaux;
(4) Isaac Lea

begin anew in a different line. With the disposition of the collection above mentioned, he turned his attention to microscopic mounts of crystals and at the time of his death was owner of a valuable collection of old coins. He also at one time collected meteorites.

The William S. Vaux of Philadelphia mentioned above in Mr. Gordon's list was one of the noted collectors of his time. For several years his was the finest general collection in America, though later surpassed by that of Clarence S. Bement noted above. He bequeathed the collection on his death to the Philadelphia Academy of Sciences, with a few reservations which passed into the hands of George Vaux, Jr., also of Philadelphia, who built up around them a second collection of excellent quality.

Dr. Isaac Lea, a member of a Philadelphia publishing house in the early part of the nineteenth century, sought recreation from business cares in natural history studies and made large and valuable collections. Aside from mineralogy he was particularly interested in the *Unionidae*, a family of bivalve mollusks concerning which he became a recognized authority. Both of these collections came ultimately into the possession of the National Museum, though the gem minerals remained for some years in the possession of his daughter, Mrs. Frances Lea Chamberlain. In this portion of the collection, her husband, Dr. L. T. Chamberlain, had manifested a lively interest, and for a time gave his services, in the capacity of an "honorary curator," to its care and upbuilding, ultimately bequeathing a specified sum, the income from which should be devoted to this work. This briefly is the history of the Isaac Lea collection of gems and precious stones in the National Museum.

A collection of more recent date than that of Wm. S. Vaux was that of the late Col. Washington A. Roebling (1837-1926), an engineer of wide reputation, best known to the general public as builder of the Brooklyn suspension bridge. In seeking relaxation from the strain on a weakened physique he turned his attention to the collecting of minerals. Unable to undergo the physical discomforts of travel and active work in the field, but fortunately endowed with the necessary financial means, he did a large share of his collecting by correspondence, and there is probably not a dealer or collector of importance in the world who has not in his files one or more letters written in the fine, almost womanly hand for which the Colonel was noted. He sought not merely the beautifully developed specimens, but those that were rare—indeed, his aim was to secure a representative of every known mineral however insignificant and uninteresting in appearance it may have been. While not himself a man of research in mineralogy he fully appreciated the work of those that were, and his materials, even the choicest, were always accessible to authentic workers. His collection at the time of his death comprised some 16,000 individual specimens, lacking but about a dozen representatives of every known well-defined species. Its great value lay not more in the rare beauty and excellence of some of the specimens than in its completeness.

Among the more striking objects of the collection is a wonderful blue apatite from Auburn, Maine; two fine trillings of chrysoberyl; a collection of Arkansas diamonds; a well developed cubical crystal of black diamond, 15 mm. in diameter; two large pink tourmalines said to be among the finest known, from Mesa Grande, California; a beautiful wine-red cut topaz weighing 93.6 carats; a cleavage section of a monster topaz weighing some forty-five pounds; and a magnificent series of opals including the largest known black mass, still uncut, weighing 18.6 ounces avoirdupois. It is an interesting idiosyncrasy of the man that he would accept from a member of his family as a present a mineral he would not himself buy on account of its high price. After his death the collection, together with a generous endowment for its care and future growth, was presented by his son, John A. Roebling, to the National Museum.

A composite collection to which the National Museum has lately fallen heir was built up through three successive generations of the same family. The nucleus was formed by Mr. Mahlon Dickerson, of Dover, N. J., who began collecting in the early part of the nineteenth century. His collection passed into the hands of his nephew, Frederick Canfield, Sr., who added to it until it comprised some 1,600 specimens, when in turn it came into the hands of his son of the same name. The younger Canfield kept this collection intact, building up one of his own independently, to which he added from time to time, and on his death in 1926 willed the entire lot, which comprised some 9,000 specimens, to the National Museum. Canfield was a mining engineer, who, like others of his profession, traveled extensively and was thus able to secure many rare and valuable specimens, both by purchase and in the field. That portion of the collection formed by his father and Mahlon Dickerson comprised not merely materials from classic European localities, but was of distinctive value on account of materials collected previous to 1860 from areas no longer available. It included large crystal groups, some of them hundreds of pounds in weight, of jeffersonite, franklinite, gahnite, garnet, and many fine masses of calamine, zincite, etc., of a quality not equaled elsewhere. Of the material added by himself the most noteworthy was a series of Bolivian silver ores and an iron meteorite weighing forty-two pounds. These ores include the largest known mass of argyrodite, a mineral consisting largely of the rare element germanium. There is also a large cleavage piece of topaz weighing ninety-five pounds (43.18 kilograms) and entire suites of such rare minerals as benitoite, neptunite, etc.

Possessed of a sufficient income, Mr. Canfield subsidized workmen in the railway tunnels and stone quarries of northern New Jersey to gather for him the choicest specimens as the work progressed, and his professional connection with the mines at Franklin Furnace enabled him to keep pace with the new and rare minerals constantly found there. It was his endeavor, so far as practicable, to continually improve the quality of his collection by replacing inferior with better specimens of the same mineral as opportunity offered. Occasionally a newly described mineral or a new find would apparently take his fancy and he would obtain a complete suite if such were available. Such suites of benitoite, neptunite, bixbyite, etc., mentioned above as found in the collection, are now well-nigh priceless. Many of the specimens owe much of their beauty and value to the long hours of painstaking work which he spent in removing the matrix from crystal groups.

Mr. Canfield never married, but may be said to have been wedded to his collection. After the death of his mother he lived in a picturesque house situated in a grove of pines on a hilltop, near Dover, New Jersey, with no companions other than an elderly housekeeper and a gardener. His time was largely given up to his hobbies—first, his minerals; second, his coins, of which he had a very valuable assemblage; and third, the study of his family history and genealogy. The mineral collection was housed in beautiful oak and mahogany cabinets, the specimens neatly labeled, catalogued, and numbered.

Mr. A. F. Holden of Cleveland, Ohio, who made one of the largest and finest of recent collections, was in 1888 a graduate of Harvard where he had achieved fame as a football player. Selecting mining engineering as his profession he shortly became possessed of a considerable income, and his interest becoming aroused by the beauty in color and form of the crystallized orpiment from the mercury mines of Utah, he entered the lists as a collector in 1895, with more than a fair start, and shortly outranked all, or nearly all competitors. He collected "with an enthusiasm and intelligence which resulted in a wide and discriminating knowledge. He aimed [as did Col. W. A. Roebling] at a complete systematic collection of all species and varieties even the rarest, but cared only incidentally for large 'show' specimens." The bulk of his collection consisted of specimens of a size easily handled and selected for their beauty, rarity, and perfection of crystalline development, and included some of the most magnificent examples known of the California kunzites and red tourmalines. This collection, amounting to upwards of 6,000 specimens, together with a handsome endowment for its upkeep, he willed in 1913 without restrictions to Harvard University, placing it far in the lead of all university collections of America.

No history of mineralogy or of mineral collectors could be considered complete that did not contain a generous reference to Prof. Chas. U. Shepard of Amherst College. Not merely was he a pioneer in mineralogy and author of one of the earliest American textbooks on the subject, but an enthusiast in the study of meteorites as well. His first collection, it is stated by Canfield, was purchased by the college and destroyed by fire in 1880. His meteorite collection was fortunate enough to escape and remains one of the features of the college museum. The collections of both minerals and meteorites in his possession at the time of his death were given by his son to the National Museum. They were of particular value in containing many types and specimens of historic interest.

The Dutchman, Troost, who figured conspicuously in the early annals of American geology, was also an enthusiastic collector and on his death left some 20,000 specimens of minerals and fossils which were sold to the Louisville Public Library.

Wm. J. Jefferies of Chester, Pennsylvania, was another old-time collector whose choice areas were eastern Pennsylvania and northern New York. He not merely purchased, but himself collected, and in 1904 sold his collection to the Carnegie Museum at Pittsburgh for more than $20,000.

Thus far we have mentioned only what may be called general collections, *i.e.*, collections which ranged throughout the entire field of mineralogy. Many collectors, however, confined themselves to special groups or regions. One of the most celebrated collections of Maine tourmalines, a few years ago, was that of A. G. Hamlin of Bangor, Maine, who limited himself wholly to the beautiful green products of the feldspar mines at Paris Hill. This was first described by him with colored illustrations, natural size, in a little volume entitled *The Tourmaline in 1873*, and later in a larger work, *The History of Mount Mica*, published in 1895. The collection was later purchased by Mr. James Garland of New York City and presented to Harvard University.

Messrs. John Daniels and W. E. Parnall of Calumet, Michigan, and Charlie Quarles of Milwaukee interested themselves chiefly in their own localities and made large collections of minerals from the Lake Superior copper mines, that of the last mentioned having later passed into the possession of the Milwaukee Public Museum. A collection made by B. B. Chamberlain of New York City, which was purchased by the New York Mineralogical Club and is now in the American Museum of Natural History, consisted exclusively of minerals found on Manhattan Island. A collection made by Prof. G. J. Brush was especially noteworthy for the perfection of crystallization of many of its individuals and the number of types, *i.e.*, specimens that had served as the basis for description of the species. This collection, valued at $40,000, he presented to the Sheffield Scientific School.

Still other collectors are even more limited in their range, confining themselves to minerals of perfect crystal development or to those of gem quality. A collection of cut stones in a case prepared to be carried in the pocket

PLATE 74

1

2

3

4

(1) Washington A. Roebling; (2) F. A. Canfield;
(3) George F. Kunz; (4) W. S. Disbrow

is not so much of a rarity as some of the readers of this volume may think, and a select series of cut opals may serve for periodic diversion a better purpose than a card game or the cinema.

Other collections of which but brief mention can be made are those of Lewis C. Beck (1818–1847), which is kept intact in the college museum in New Brunswick, New Jersey; of Maynard Bixby, which consisted largely of extra-quality specimens from the western mining regions and which passed into the keeping of the Field Museum in Chicago; the John H. Campion collection of gold specimens, which he presented to the State Museum in Denver; the J. T. Cardeza collection of minerals from Chester and Delaware counties, Pa., now in the University of Pennsylvania; the A. H. Chester collection, presented to Rutgers College; the Joseph Delafield collection, given by his family about 1890 to the New York University, with the stipulation that it should be kept intact; the D. Delsner collection of Colorado minerals, sold to the State and now in the Colorado Bureau of Mines; the W. F. Ferrier collections, sold to the University of Toronto and McGill University; the S. Godon collection, subsequently purchased by Joseph Wharton and presented to the Philadelphia Academy of Sciences; the G. W. Hammon collection of Maine minerals, presented by him to Bowdoin College; the E. P. Hancock collection of exceptionally fine specimens from Franklin Furnace, New Jersey, the Tilly Foster mines of New York, and the mica mines of Amelia County, Virginia, purchased in 1916 by Harvard University; the W. E. Hidden collection of North Carolina minerals, sold to the University of Vienna; the Henry S. Howe collection of Nova Scotia minerals, prepared for the Paris Exposition of 1867 and afterward purchased by the government and placed in the provincial museum in Halifax; the W. J. Jefferies collection of minerals largely from eastern Pennsylvania and northern New York, sold to the Carnegie Museum of Pittsburgh; the J. G. Manchester collection containing interesting material from the Erie Cut through Bergen Hill, presented to the Public Library of Fall River, Massachusetts; the H. D. Miller collection of extra quality of some 4,100 specimens, given to the Hartford, Connecticut, museum in 1914; and the Theodore D. Rand collection of upward of 20,000 specimens, presented by his daughter to Bryn Mawr College.

Among collectors still active, mention must be made of George F. Kunz, now of Tiffany and Company, New York, known throughout the commercial world as an expert on gems and as a collector of minerals wherever the calling finds a practitioner. Born in New York, a region abounding in minerals and with an ingrained taste for the pursuit, he began collecting as a mere youth and while yet in his "teens" had sold his first collection to the University of Minnesota for something like $400. From the start thus made he has followed consistently the profession of collector and dealer and has capitalized his acquired knowledge to the mutual benefit of himself and the trade. During all the years since the date of his first sale he has drifted more and more into the specialized line of gem stones, and has written several authoritative treatises on the subject. Today he is recognized as a leading authority and a member of the most widely known of American jewelers' establishments. It is a safe statement that there is no collection of note in the United States that has in it—particularly if it be a collection of precious stones—material in the securing of which Dr. Kunz has not had a hand.

Mention should also be made of the genial Dr. W. S. Disbrow, who collected not for himself but for others. His systematic series he deposited in the Newark, New Jersey, public library, but many of his finest specimens from the trap rocks and zinc mines of New Jersey were given to the National Museum. He was a man of unusual judgment and ranged widely; old silver and coins, together with rare books, were promptly gathered in whenever his practice as a family physician permitted, and almost as promptly parted with did he find they would be of greater value elsewhere than in his own collections.

One of the most inveterate of collectors of minerals and meteorites—both as collector and dealer—was the late H. A. Ward of Rochester, New York, founder of the well known Ward's Natural Science Establishment. Not satisfied with buying and selling to others, he gave free rein to his hobby and built up for himself one of the numerically largest meteorite collections in the world, which after his death became the property of the Field Museum of Natural History in Chicago. Having once heard of a meteorite, stone or iron, fall or find, Ward was never satisfied until he had secured a sample—it might be ever so small—for his collection. In pursuit of his hobby he wandered literally all over the earth, examining every collection and exchanging, begging, or buying materials. He was a man of wonderful enthusiasm and agreeable personality and did not hesitate to exercise any or all of his powers of persuasion, linguistic or financial, to accomplish his purpose.

CHAPTER VII

THE CUTTING OF GEMS

It is a fair assumption, if indeed it be not a proven fact, that when primitive or ancient man selected a stone for gem purposes he based his selection wholly on a consideration of color. Even the Navaho Indian of the present time comes down to his trading post wearing a necklace of rough bits of turquoise, and records of primitive man in all ages tell the same story. Indeed, until the custom of cutting stones in faceted form came into vogue, little else could be expected. The great diamonds of history failed to realize their full beauty until recut by modern methods.

A gem stone is cut to improve its appearance and bring out its hidden beauties. Many precious stones entirely lack appeal in the rough state; even the diamond hides the fire which chiefly recommends it. Each individual mineral presents different problems according to the effect desired. We strive for the fire in the diamond, but for the pure blue color in the sapphire; hence these call for different treatment.

The form into which a gem should be cut depends primarily upon whether it is transparent, translucent, or opaque. In the last case, since faceted cutting adds nothing to the gem, a smoothly rounded surface is employed. Faceting will best bring out the beauty of the transparent stone. In this group the index of refraction of the mineral and the degree of its dispersion of light further influence the cut. Its proportions must be so determined as to return the maximum amount of light to the upper part of the stone. The cut known as the brilliant serves best to bring out the remarkable fire and brilliance of the diamond. The octahedral form of its crystal is made the basis of this cut, and if the natural stone is not already in this form, it may be so trimmed by means of its ready octahedral cleavage, as has already been noted (page 181). To sacrifice as little as possible of the precious material must be a further aim of the cutter. The Orientals fashioned their stones into irregular shapes, the primary consideration being size and not beauty. In the modern cuts beauty is the effect sought and results frequently in the sacrifice of a large part of the stone. Thus, the Cullinan diamond, originally weighing 3,025 carats, yielded but 1,036 carats of cut stones, or only thirty-four per cent of its original weight. The Star of South Africa, originally an octahedral stone, fell from eighty-three to forty-six carats on cutting, a loss of forty-five per cent. The increased beauty of the gem compensates for this loss of precious material.

In the following pages are given explanations and names of the forms now commonly cut, and brief mention of the manner in which the work is done.

The several styles of cut may all be brought under one or the other of the following heads: (1) those bounded by plane surfaces only; (2) those bounded by curved surfaces only; (3) those bounded by both curved and plane surfaces. The several examples under the above heads may be tabulated thus:

1. Bounded by plane surfaces:
    - Brilliant cut.
    - Double brilliant or Lisbon cut.
    - Half brilliant or single cut.
    - Trap or split brilliant cut.
    - Portuguese cut.
    - Star cut.
    - Rose cut, or briolette.
    - Step brilliant or mixed cut.
    - Table cut.

2. Bounded by curved surfaces:
   - Double cabochon cut.
   - Single cabochon cut.
   - Hollow cabochon cut.
3. Bounded by curved and plane surfaces: Mixed cabochon cut.

BRILLIANT CUT

The brilliant cut may be described as two truncated pyramids placed base to base. The upper pyramid is called the *crown*, and is so truncated as to give a large plane surface; the lower one, called the *pavilion*, terminates almost in a point. The line of union of the two pyramids is called the *girdle*, and is the widest part of the stone. This fashion of cut, though occasionally modified as to the size, mutual proportions, and even the number of facets, requires, when perfect, 58 facets. The uppermost facet is called the *crown*, and is formed by removing one-third of the thickness of the fundamental octahedron; the lowermost facet is called the *culet*, or *collet*, and is formed by removing one-eighteenth of the thickness of the stone (*a* and *b*, in text fig. 9). The triangular facets touching the table (S in *c*, fig. 9) are called *star facets*; those touching the girdle fall into two groups, *skill facets* (E in *c*) and *skew facets* (D in *c*). The corner facets touching the table and girdle on the crown (B in *c*), and the culet and girdle on the pavilion (Q in *d*) are called *quoins*. The facets between the quoins, and touching the table and girdle when on the crown, and the culet and girdle when on the pavilion, are called, respectively, *bezel* facets (A in *c*) and *pavilion* facets (P in *d*). The total number of facets are distributed as follows: 1 table, 16 skill facets, 16 skew facets, 8 star facets, 8 quoins, 4 bezel facets, 4 pavilion facets, and 1 culet, as shown in *c*, *d*, and *e* of the text figure, representing the top, side, and bottom views of a brilliant with 58 facets. Occasionally the cut is modified by cutting extra facets around the culet, making 66 in all.

The brilliant cut is especially applied to the diamond, and when perfect should be of the following proportions: From the table to the girdle, one-third, and from the girdle to the culet, two-thirds of the total. The diameter of

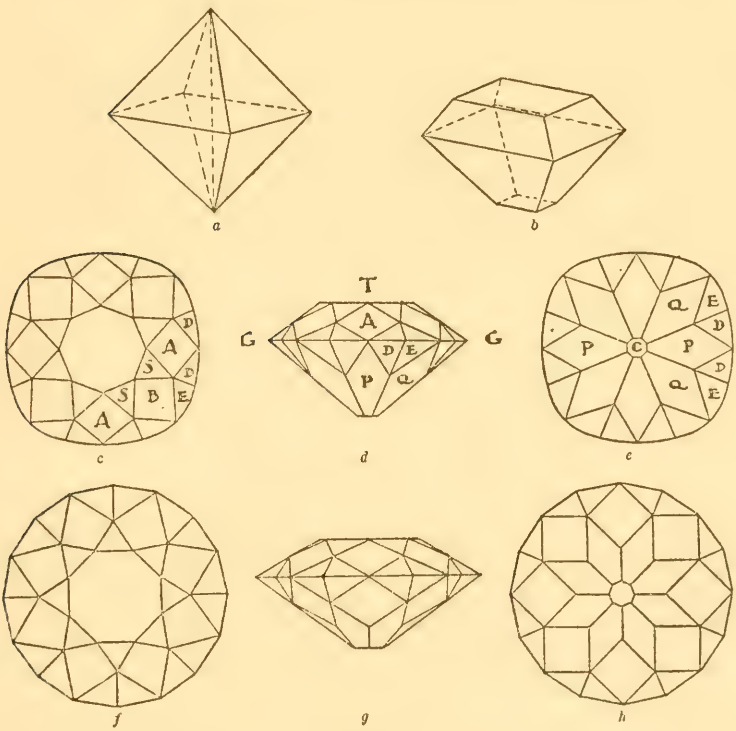


Fig. 9. The brilliant. *a* and *b*, manner in which the brilliant is derived from the fundamental form; *c*, *d*, and *e*, top, side, and back views of brilliant with 58 facets; *f*, *g*, and *h*, top, side, and back views of modified brilliant with 66 facets

the table should be four-ninths of the breadth of the stone. When applied to other stones these proportions are more or less modified to suit their individual optical constants.

DOUBLE BRILLIANT CUT

The double brilliant, or Lisbon, cut differs from the full brilliant in having the foundation squares divided horizontally into two triangular facets, 74 in all. The figure shows top (*a*), side (*b*), and bottom (*c*) views of this fashion.

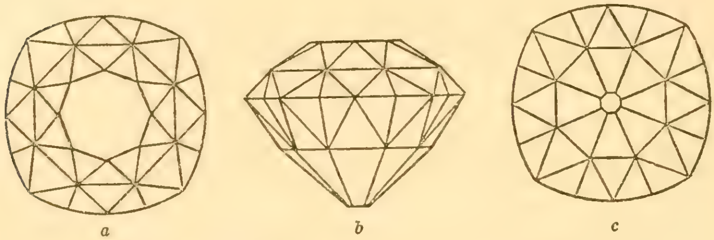


FIG. 10. The double brilliant. Top *a*, side *b*, and back *c*, views

HALF BRILLIANT CUT

The half brilliant, single, or old English cut is the simplest form of the brilliant, and is generally employed for stones too small to admit of numerous facets. The figure shows top (*a*) and side (*b*) views of this style of cut. Occasionally the top is cut so as to form a star (*c* in fig. 11) and then called English single cut.

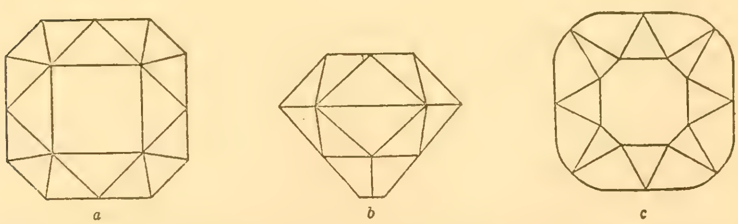


FIG. 11. The half brilliant. Top *a*, and side *b*, views of the half brilliant. In *c* the top is cut in the form of a star, then called English brilliant

TRAP BRILLIANT CUT

The trap brilliant, or split brilliant, is a form with two rows of lozenge-shaped facets, and three rows of triangular-shaped facets, making 42 in all.

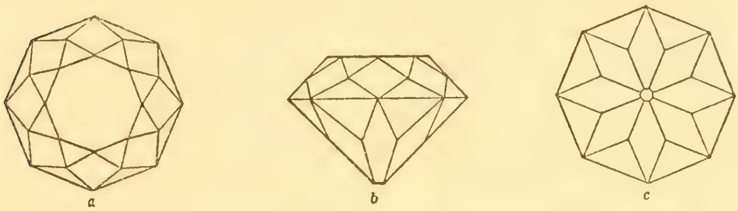


FIG. 12. The trap brilliant. Top *a*, side *b*, and back *c*, views

PORTUGUESE CUT

The figure shows the top, side, and bottom views of the Portuguese cut, which has two rows of rhomboidal and three rows of triangular facets above and below the girdle.

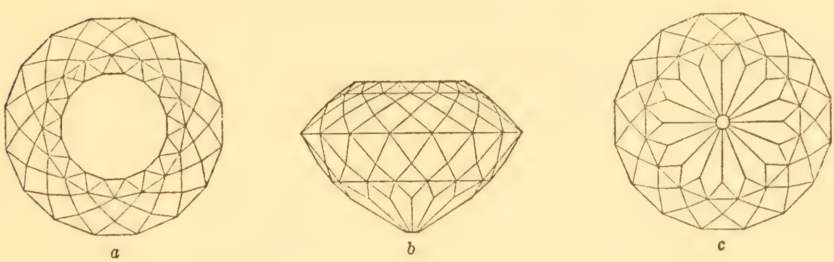


FIG. 13. The Portuguese cut. Top *a*, side *b*, and back *c*, views

STAR CUT

The figure shows the front and back views of the star cut. The table is hexagonal in shape, and is one-fourth of the diameter of the stone; from the table spring six equilateral triangles, whose apices touch the girdle, and these triangles, by the prolongation of their points, form a star.

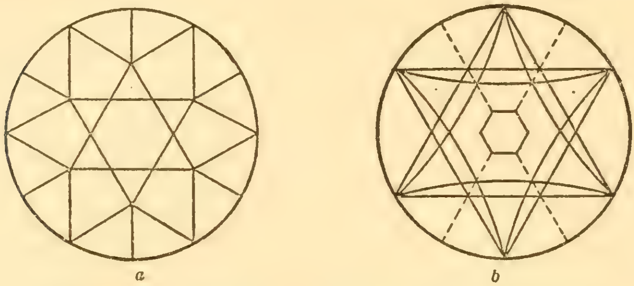


FIG. 14. The star cut. Front *a*, and back *b*, views

ROSE CUT

The rose cut differs from the brilliant cut in that the crown consists of triangular or star facets, whose apices meet at the point or crown of the rose. The base lines of these star facets form the base lines for a row of skill facets whose apices touch the girdle, leaving spaces which are each cut into two facets. The base may be flat or the bottom may be cut like the crown, making a double rose or briolette cut. The shape of a rose-cut stone may be circular, oval or indeed any other that the rough gem may permit.

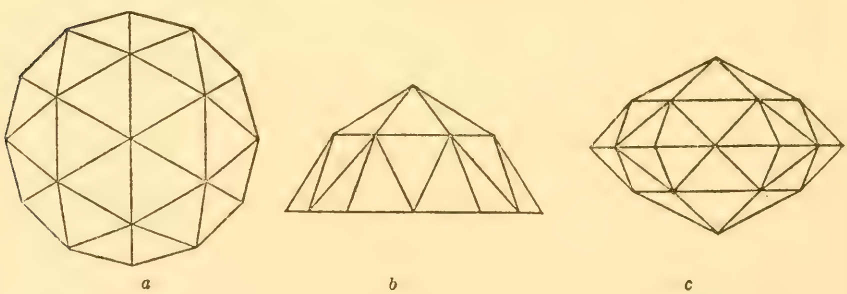


FIG. 15. The rose cut. *a* and *b*, top and side views; *c*, side view of double rose

TRAP OR STEP CUT

In the trap or step cut the facets run longitudinally around the stone from the table to the girdle and from the girdle to the culet. There are usually but two or three sets of step facets from the table to the girdle, while the number of steps from the girdle to the culet depends upon the thickness and color of the stone. The fashion is best adapted to emeralds and other colored stones.

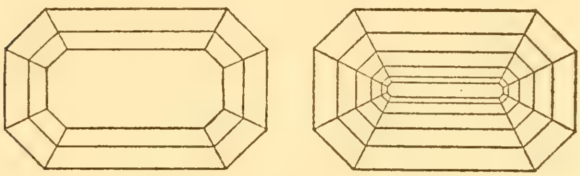


FIG. 16. Upper and under sides of trap cut

STEP BRILLIANT OR MIXED CUT

Here the form from culet to girdle is the same as that of the trap cut, while from the girdle to the table the stone is brilliant cut, or the opposite.

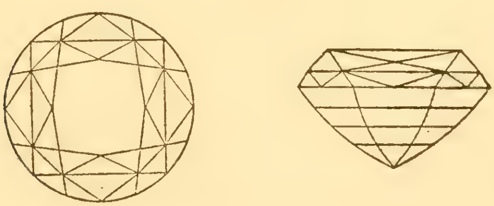


FIG. 17. The step brilliant cut

TABLE CUT

The table cut consists simply of a greatly developed table and culet meeting the girdle with beveled edges. Occasionally the 8 edge facets are replaced by a border of 16 or more facets.

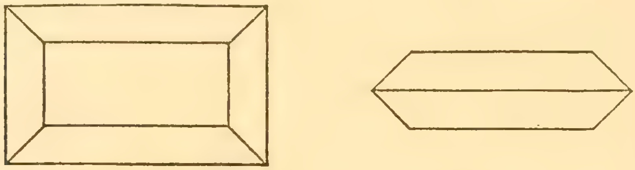


FIG. 18. Top and side views of table cut

CABOCHON CUT

The cabochon cut is usually applied to opaque, translucent, deep-colored, or chatoyant stones. The double cabochon is usually cut with a smaller curvature on the base than on the crown. The single cabochon is a characteristic cut for the turquoise. The hollow cabochon is adapted to very deep-colored transparent stones. The mixed cabochon has either the edge or side faceted, or both. In all of the cabochon cuts the arches may be of a varying degree of flatness, depending upon the nature of the stone.

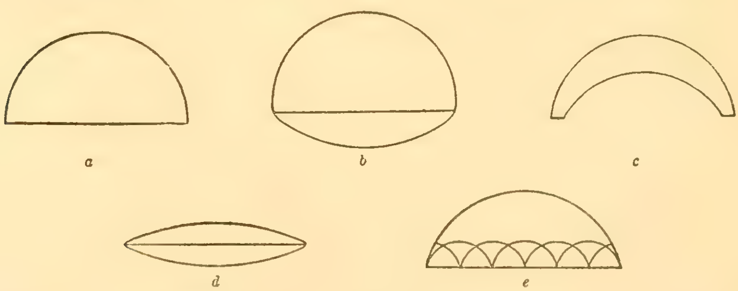


FIG. 19. The cabochon cut. *a*, the single cabochon; *b*, the double cabochon; *c*, the hollow cabochon; *d*, flat or tallow top cabochon; *e*, mixed cabochon.

CAMEO AND INTAGLIO

The term *cameo* is applied to any engraving in relief upon the surface of a gem, usually upon a stone like onyx or a shell composed of layers of different colors, the engraving being of sufficient depth to expose the underlying layers and produce the desired contrast. An *intaglio* differs in being an incised engraving and usually upon a stone of uniform color throughout.

The cutting of a stone for gem purposes does not, however, exemplify the highest development of the art. The work of grinding facets is largely mechanical and offers little opportunity for artistic expression. More deserving of admiration is the work of the artisan on a material less subject to geometric laws. The antique carving of jade by the Orientals, as seen in the Bishop collection in the Metropolitan Museum of New York, perhaps exemplifies the art of stone cutting at its highest. There exist, however, abundant examples of artistic carvings in less refractory and less expensive material as typified by the animal figures, perfume bottles, shallow trays and other objects in clear glassy or rose quartz, agate, or like materials. Much ingenuity is often practiced in this work in bringing out in striking relief some inequality in color or venation of the materials.

CHAPTER VIII

GEMS MENTIONED IN THE BIBLE

THE Bible contains three lists of gems. The first of these is an account of jewels on the ephod of Aaron. The ephod is described as having a front part and a back part fastened at each shoulder with an onyx mounted in gold and engraved with the names of the children of Israel, six on each stone, to memorialize the Lord of the promise made to them (Exodus, xxviii, 6–12). The breastplate was made of the same material as the ephod, and folded so as to form a kind of a pouch in which the Urim and Thummim were placed (Exodus, xxxix, 9). The external part of this gorget, or "breastplate of judgment," was set with four rows of gems, three in each row, each stone set in a golden socket and having engraved upon it the name of one of the twelve tribes of Israel (Exodus, xxviii, 17-21).

In many instances the equivalent of the Biblical names of gems is uncertain in the nomenclature of modern mineralogy, and as a consequence there are several distinct lists of names given for the stones in the breastplate. In the section of comparative religions in the National Museum is a very old silver breastplate employed as an ornament for the manuscript copy of the Torah, or Pentateuch, used in an ancient synagogue. The twelve stones, with the names of the twelve tribes, according to it are as follows: Garnet, Levi; diamond, Zebulon; amethyst, Gad; jasper, Benjamin; chrysolite, Simeon; sapphire, Issachar; agate, Naphthali; onyx, Joseph; sard, Reuben; emerald, Judah; topaz, Dan; beryl, Asher.

GEMS MENTIONED IN THE BIBLE

The following lists taken from *Biblical Antiquities* by Adler and Casanowicz[1] give the names of these stones in the original and in the Septuagint, together with the meaning adopted by most authorities, the rendering of the Revised Version, both in text and margin being added in parentheses:

1. *Odem* (*sardion*), carnelian (sardius, ruby).	2. *Pitdah* (*topazion*), topaz or peridot.	3. *Bareketh* (*smaragdos*), smaragd or emerald (carbuncle, emerald).
4. *Nofek* (*anthrax*), carbuncle, probably the Indian ruby (emerald, carbuncle).	5. *Sappir* (*sapfeiros*), sapphire or lapis lazuli (sapphire).	6. *Yahalom* (*iaspis*), onyx, a kind of chalcedony (diamond, sardonyx).
7. *Leshem* (*ligyrion*), jacinth, others, sapphire (jacinth, amber).	8. *Shebo* (*achates*), agate.	9. *Achlamah* (*amethystos*) amethyst.
10. *Tarshish* (*chrysolithos*), chrysolite, others, topaz (beryl, chalcedony).	11. *Shoham* (*beryllion*), beryl (onyx, beryl).	12. *Yashpeh* (*onychion*), jasper.

The second list is that given in the description of the ornaments of the Prince of Tyre (Ezekiel, xxviii, 13):

1. *Odem.*	2. *Pitdah.*	3. *Yahalom.*
4. *Tarshish.*	5. *Shoham.*	6. *Yashpeh.*
7. *Sappir.*	8. *Nofek.*	9. *Bareketh.*

The third list is that given in the description of the Heavenly City (Revelation, xxi, 19, 20). As in the preceding list, the word used in the original, or Greek, is followed by the rendering given by most authorities, that of the Revised Version in parentheses:

1. *Iaspis*, jasper.	2. *Sapfeiros*, sapphire or lapis lazuli.	3. *Chalkedon*, chalcedony
4. *Smaragdos*, smaragd (emerald).	5. *Sardonyx*, sardonyx.	6. *Sardios*, sardius.
7. *Chrysolithos*, chrysolite.	8. *Beryllos*, beryl.	9. *Topazion*, topaz.
10. *Chrysoprasos*, chrysoprase.	11. *Hyakinthos*, jacinth (sapphire).	12. *Amethystos*, amethyst.

[1] *Rep. U. S. Nation. Mus.*, 1896, p. 943. A collection of these stones is on exhibition in the division of Old World archeology, department of anthropology.

In addition to the gems enumerated in these lists, there is mentioned the diamond by the Hebrew name of *shamir* (Jeremiah, xvii, 1; Ezekiel, iii, 9; Zechariah, vii, 12); amber, Hebrew *hashmal* (margin of Revised Version gives *electrum*) (Ezekiel, i, 4); crystal (quartz), Hebrew *qerah* and *gabish* (Ezekiel, i, 22; Job, xxviii, 18; Revelation, iv, 6).

The complete list of gems mentioned is as follows:

Agate, Hebrew *shebo*.—One of the stones in the breastplate of judgment. (Exodus xxviii, 19.)

Amber, Hebrew *hashmal*.—Ezekiel i, 4. Some render the Hebrew *leshem* as amber, thus making it one of the gems of the breastplate. (Exodus xxvii, 19.)

Amethyst, Hebrew *ahlamah*.—One of the stones in the breastplate. (Exodus xxviii, 19). In Revelation xxi, 20, it is mentioned as garnishing the twelfth foundation of the heavenly Jerusalem.

Beryl, Hebrew *shoham*.—One of the stones in the breastplate. (Exodus xxviii, 20.) Mentioned as one of the ornaments of the King of Tyre. (Ezekiel xxviii, 13.) In Revelation it is spoken of as adorning the eighth foundation of the Holy City.

Carbuncle, Hebrew *nofek*.—One of the stones in the breastplate. (Exodus xxviii, 18; see also Ezekiel xxviii, 13.) The word *nofek* has been rendered ruby.

Carnelian, perhaps the Hebrew *odem* of the breastplate (Exodus xxviii, 17), and the sardius in Revelation xxi, 20. In Revelation iv, 3, of the Revised Version, is the rendering sardius. In the Authorized Version the reading is: "And he that sat was to look upon like a jasper and a *sardine* stone." In the Vulgate: "Et qui sedebat similis erat aspectui lapidis jaspidis et sardinis." The Textus receptus (Greek) is: Καὶ ὁ καϑήμενος ἦν ομοιος ὁράσει λίϑῳ ἰασ̈ πιδι; καὶ σαρδίνιῳ. All other editions have for the last word, σαρδίῳ. It is evident that the Vulgate and the Authorized Version simply followed the Textus receptus, and that the correct rendering is "sardius" and not "sardine stone."

Chalcedony.—The Hebrew *tarshish* (Exodus xxviii, 20) has been rendered chalcedony. In Revelation xxi, 19, it is enumerated in the description of the foundation of the New Jerusalem.

Chrysolite.—(See Revelation xxi, 20.) The Hebrew *tarshish* (Exodus xxviii, 20) has been rendered chrysolite.

Chrysoprase.—One of the stones in the foundation of the Heavenly City. (Revelation xxi, 20.)

Diamond, Hebrew *shamir*.—(See Jeremiah xvii, 1; Ezekiel iii, 9; and Zechariah vii, 12), where it is spoken of as an object of extreme hardness. In the Authorized Version the Hebrew *yahalom* (Exodus xxviii, 18) is rendered diamond.

Emerald, Hebrew *bareketh.*—One of the stones in the breastplate. (Also see Revelation iv, 3.)

Jacinth, Hebrew *leshem.*—A stone in the breastplate. (Exodus xxviii, 19). The eleventh foundation of the Heavenly Jerusalem. (Revelation xxi, 20.)

Jasper, Hebrew *yashpeh.*—A stone in the breastplate. (Exodus xxviii, 20.) Mentioned as adorning the Prince of Tyrus (Ezekiel xxviii, 13.) One of the stones enumerated in the description of Prince of Tyrus (Ezekiel xxviii, 13.) One of the stones enumerated in the description of the Heavenly City. (Revelation xxi, 19.)

Onyx, Hebrew *shoham.*—One of the stones in the breastplate. (Exodus xxviii, 20; see also Genesis ii, 12; and Ezekiel xxviii, 13.) According to certain renderings the *shoham* is beryl. Shohams set in gold were put on each of the two shoulder straps of the ephod of the high priest, and the two were engraved with the names of the twelve tribes, six on each. (Exodus xxviii, 12.)

Pearl.—It is thought that pearl is meant by the Hebrew *peninim*, a word often employed in the Old Testament as a figure of something valuable and precious. (See Proverbs iii, 5; xxxi, 10, and Job xxviii, 18.) Jesus uses the pearl for the same purpose in Matthew vii, 6, and xiii, 45.

Ruby, Hebrew *nofek* or *odem.*—One of the gems in the breastplate. (Exodus xxviii, 17; see also Ezekiel xxvii, 13.)

Sapphire, Hebrew *sappir.*—One of the stones in the breastplate. (Exodus xxviii, 18; also mentioned in Ezekiel xxviii, 13, and Revelation xxi, 19.) Some authorities render *sappir* as lapis lazuli, and not sapphire.

Sardonyx, Hebrew *yahalom.*—One of the stones in the breastplate. (Exodus xxviii, 18.)

Topaz, Hebrew *pitdah.*—One of the stones in the breastplate. (Exodus xxviii, 17; also mentioned in Ezekiel xxviii, 13, and in Revelation, xxi, 20.)

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